APRIL 1959

JOURNAL OF THE IRON AND STEEL INSTITUTE

4 GROSVENOR GARDENS · LONDON SWI

Established 1869 · Incorporated by Royal Charter 1899

VOL. 191 PART 4

Principal Contents

Use of oxygen in duplex and stationary OH practice *by O. Pearson* 305

Some investigations on the treatment of molten iron *by W. B. Chater and J. A. Charles* 319

Practical aspects of pretreatment processes *by J. L. Harrison* 328

Use of oxygen in a modified tilting furnace *by A. Jackson* 337

Removal of hydrogen by diffusion from large masses of steel *by J. D. Hobson* 342

Distortion of high-C high-Cr die steel *by K. Sachs and G. T. F. Jay* 353

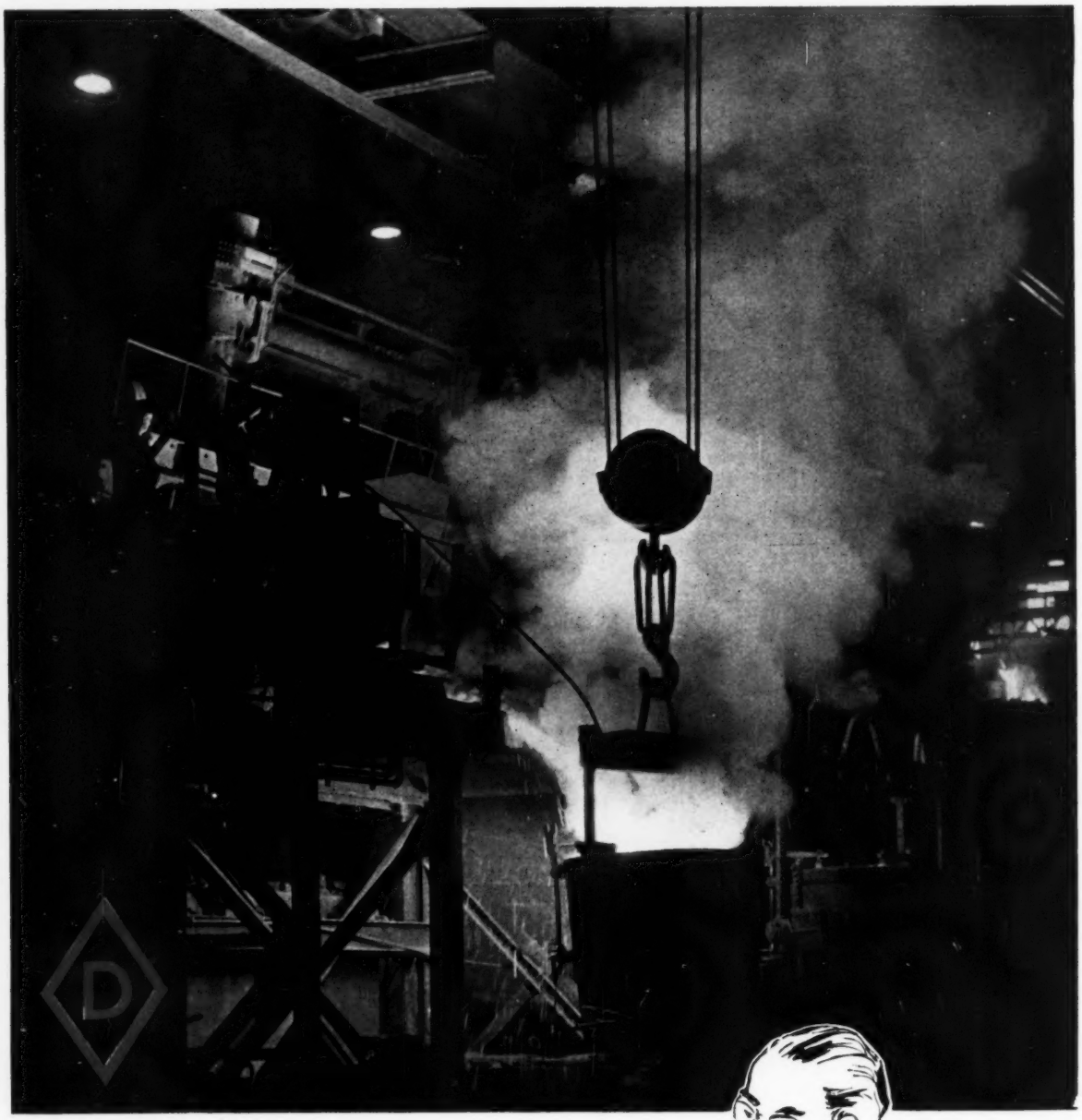
Effect of austenitizing treatment on lower bainite formation *by L. W. Graham and H. J. Axon* 361

Equipment for vacuum melting and casting *by A. S. D. Barrett and M. E. Harper* 366

Report of the 37th Engineers Group Meeting 374

News 390 Abstracts 395

A full list of contents is given on the Title Page (see page 65, Advertisement Section)



Photograph by courtesy of Thos. Firth & John Brown Ltd.

We cut ladle lining costs by 17% .....

using Dyson "LP" (low porosity) ladle lining bricks.

J. & J. DYSON LTD., STANNINGTON, SHEFFIELD

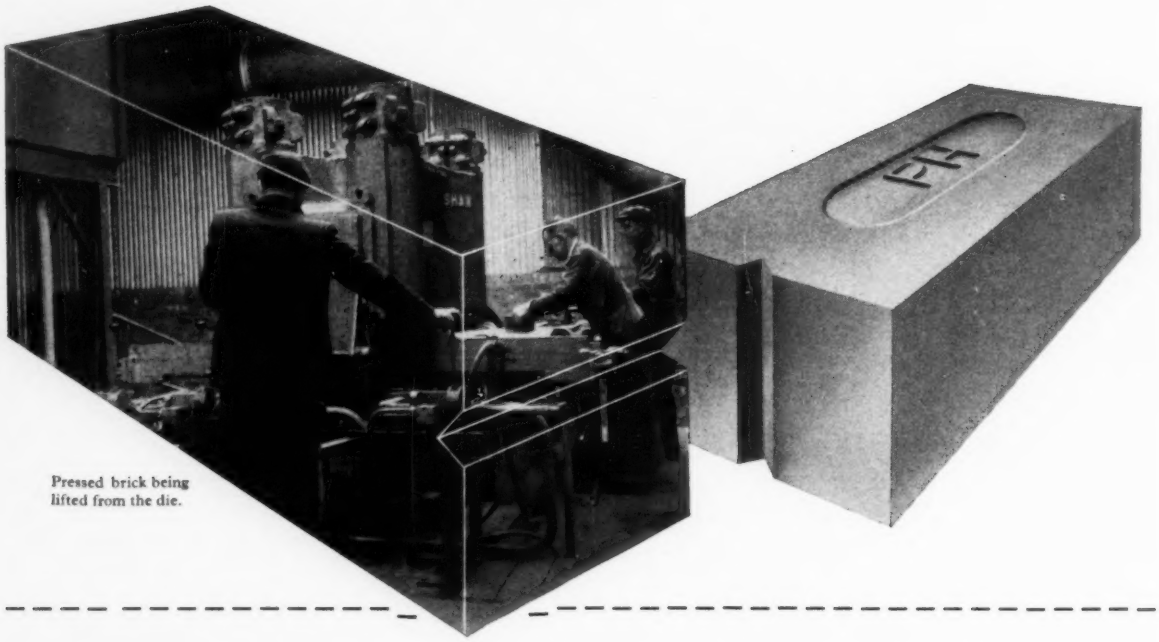
Modern Coke Oven Machinery

Wellman Combined Coke Pusher, Coal Leveller and Door Extracting Machine, designed and constructed for The Stanton Ironworks Co. Ltd., to the order of the Woodall-Duckham Construction Company Ltd.

A unique feature of this machine is the lattice-braced ram beam which is designed to obviate distortion of the ram where uneven cooling conditions occur on exposed sites.

We supply full equipment for Coke Oven Batteries, namely: Coke Pushers, Coke Guide and Door Extractors, Coal Charging Cars, Coke Quenching Cars (fixed and tilting floor types), Clay Luting Lifts, Electric and Electro-hydraulic Locomotives.

THE WELLMAN SMITH OWEN ENGINEERING CORPORATION LTD.
PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 WORKS: DARLASTON, South Staffs, & BELFAST.



Pressed brick being lifted from the die.

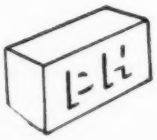
PRESSING PROBLEM SOLVED

Pickford Holland install the latest hydraulic presses for standard and special shapes

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.

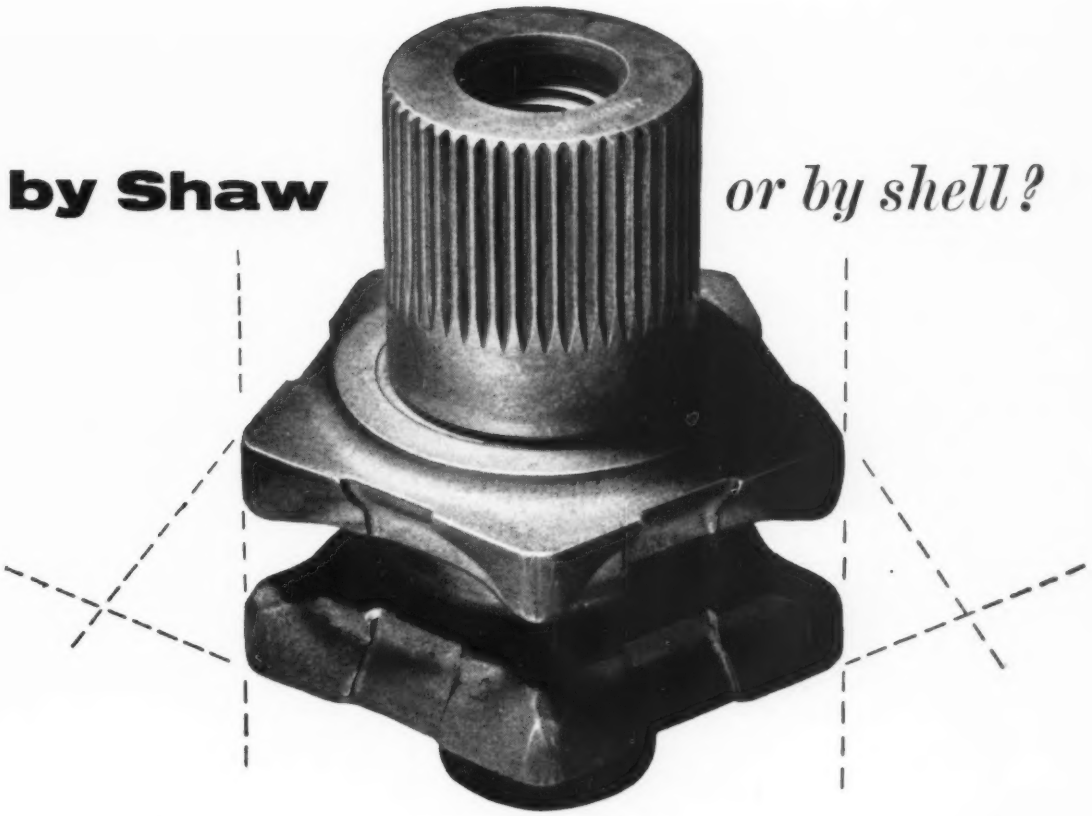


PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

PICKFORD HOLLAND & CO. LTD., 381 FULWOOD ROAD, SHEFFIELD 10. TELEPHONE: 33921

by Shaw *or by shell?*



As licensees of the Shaw Process, and producers of castings by the Shell Moulded Process as well, The PHOSPHOR BRONZE Co. Ltd. can give you an unbiased opinion on the best method to use in any instance. While castings produced by the shell moulded process are more accurately produced than by older methods, the limits cannot be held to the same high degree of accuracy as when castings are produced by the Shaw Process.

When machining time and costs make the difference, P.B. technicians are ideally placed to help your own technicians to decide their choice.

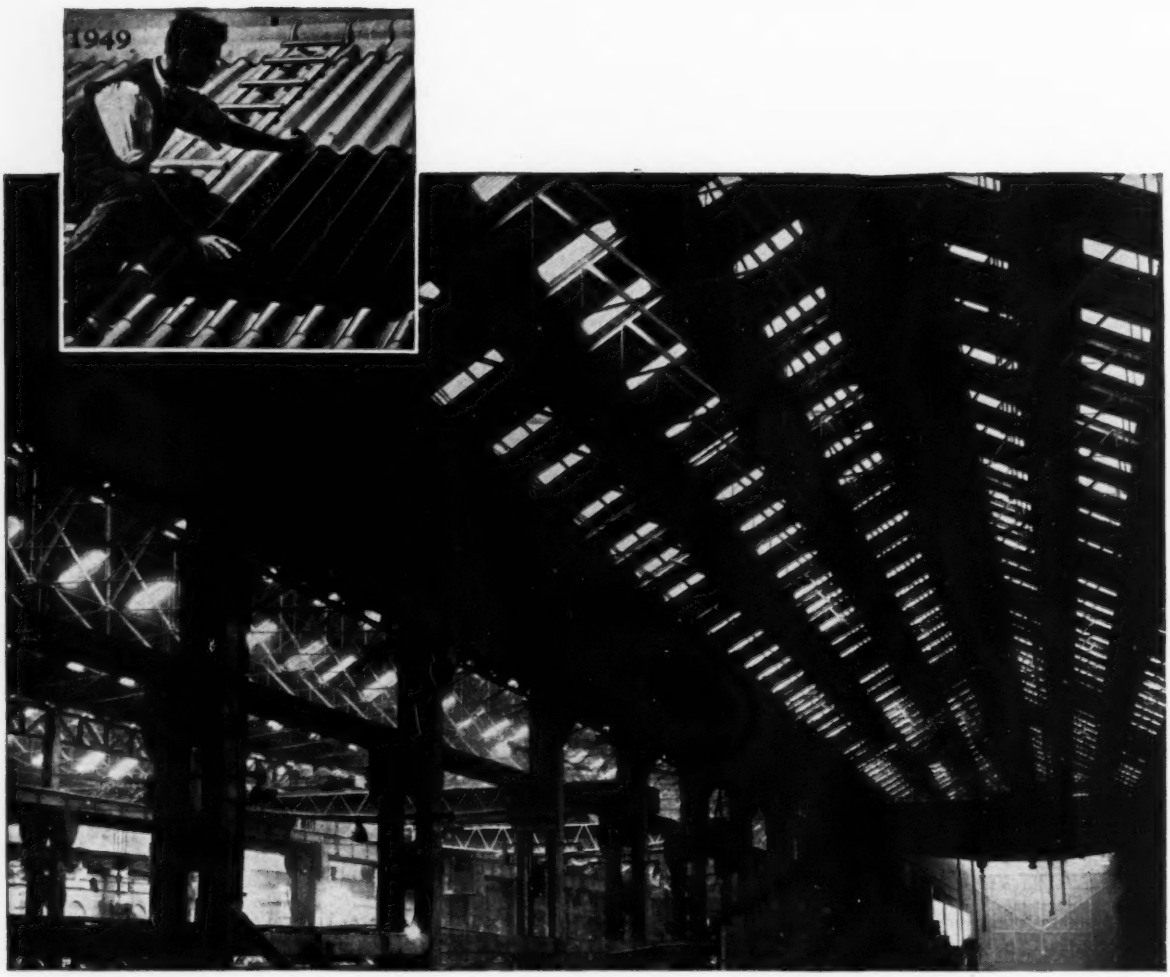
Send for a copy of comprehensive brochure covering all casting processes

The PHOSPHOR BRONZE CO. LTD.

(P.O. Box 74) BRADFORD STREET · BIRMINGHAM 5 · PHONE: MIDLAND 6821 (10 lines)

This company participates in the research, technical, and productive resources of the Birfield Group, which includes Hardy Spicer Ltd., Laycock Engineering Ltd., Kent Alloys Ltd., Forgings and Presswork Ltd., and many other famous firms

MEMBER OF THE BIRFIELD GROUP



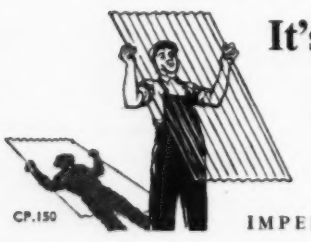
This installation of Corrugated 'Perspex' is in the factory of the North Eastern Marine Engineering Company Ltd., Wallsend, Northumberland. It has been installed over 9 years.

Corrugated 'Perspex' as efficient as ever after 9 years continuous use in engineering factory

FOR OVER 9 years Corrugated 'Perspex' has been in continuous use in a large engineering factory. Through all that time it has given good efficient service. Indeed, the North Eastern Marine Engineering Company Ltd. say in their letter that it has been so successful they have added considerable new installations of Corrugated 'Perspex'.

Corrugated 'Perspex' is immensely tough, light and unaffected by the corrosive atmosphere of most industrial areas. It withstands weather conditions in any part of the world.

It has other advantages. Corrugated 'Perspex' has a very high light transmission. It is easy and economical to install. Once in, there is an immediate saving on artificial light. There are a wide range of profiles, and if diffused daylight is desired, Opal Corrugated 'Perspex' is available.



It's as clear as daylight—it must be

CORRUGATED 'PERSPEX'

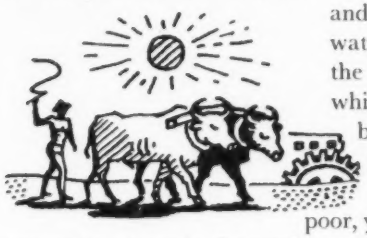
'Perspex' is the registered trade mark for the acrylic sheet manufactured by I.C.I.

IMPERIAL CHEMICAL INDUSTRIES LIMITED · LONDON · S.W.1

This is one of a series of advertisements by ***RITCHIE CALDER*** *which is appearing in the National Press to illustrate how atomic power may help man's muscle emancipation*

Muscle is the most costly power on earth

A TYPICAL SCENE in tropical countries is that of the bullock-team raising water from a well. To the chanting of the drivers, the bullocks trudge backwards and forwards, under the relentless sun, lowering the buckets into the well, hoisting the water and tipping it into the water-courses to irrigate the thirsty soil, from which both men and beasts get their food. Those peasants are poor, despairingly poor, yet they use the most expensive power in the world—muscle-power. Bullocks have to be bought, tended and fed, yet even with the meagre food and pitiful earnings of the men who drive them, the energy equivalent which they produce costs twenty times as much per unit as the energy output at Calder Hall atomic energy station.



MUSCLE POWER INEFFICIENT

A great many people in the world are poor because of necessity, they use calories in their most expensive form and energy in the most uneconomical way. Although we may glorify muscle-effort—and, indeed, laud it in the performances of athletes—it is deplorably inefficient. The advance from the steam-engine to atomic power, from the pulley-belt to automation, has represented the emancipation of man from muscle-slavery.

The paradox of power is that those who are power-deficient are power-extravagant. When we go around the house switching off lights to keep the electricity bill down, we might think of the Indian villager burning cow-dung to cook his food for his muscle-power. Because he burns that dung, instead of using it as manure, his soil is undernourished, his crops are undernourished, and he is undernourished.

This is the Misery-Go-Round of poverty; because the peasant is poor he is undernourished; because he is undernourished he under-produces; because he under-produces he is poor; and because, in 'muscle-power' countries, poverty prevails, their natural resources are underdeveloped. Such countries see in nuclear energy a break-through to industrial prosperity. The problem of how to find the money to pay for it and to train the people to handle it, is the answerable challenge of our times.

The power engineers know the answers; the mechanical engineers have created the machines. The muscle-slaves are waiting to be freed and the resources of their countries are waiting to be developed. The machine is the emancipator.

MITCHELL ENGINEERING *are designing and constructing Nuclear Power Plant to meet world needs in the New Atomic Age*

MITCHELL

MITCHELL ENGINEERING LIMITED ONE BEDFORD SQUARE LONDON

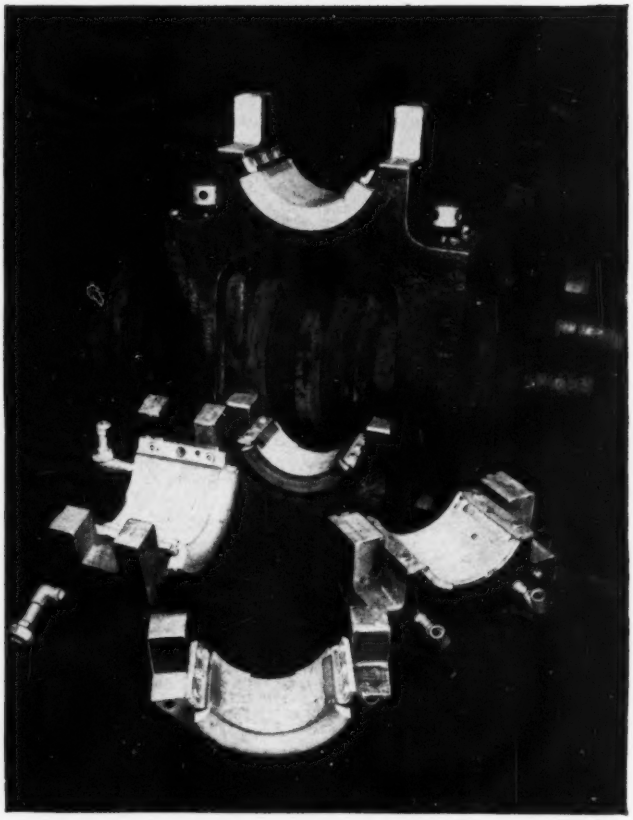
See our exhibit on the stand of
The United Steel Companies Limited at the
ENGINEERING, MARINE, WELDING AND NUCLEAR ENERGY EXHIBITION, Olympia, London, April 16-30th.
Stand No. 6, Row P, Ground Floor, National Hall.

Orkot

Rolling Mill

BEARINGS

in service
in the mills of
The United Steel
Companies Limited
have



★ **LOW FRICTION COEFFICIENTS . . .**
and
★ **IMPROVED WEAR RESISTANCE . . .**
leading to
★ **POWER SAVINGS . . .**
and
★ **LONG BEARING LIFE**

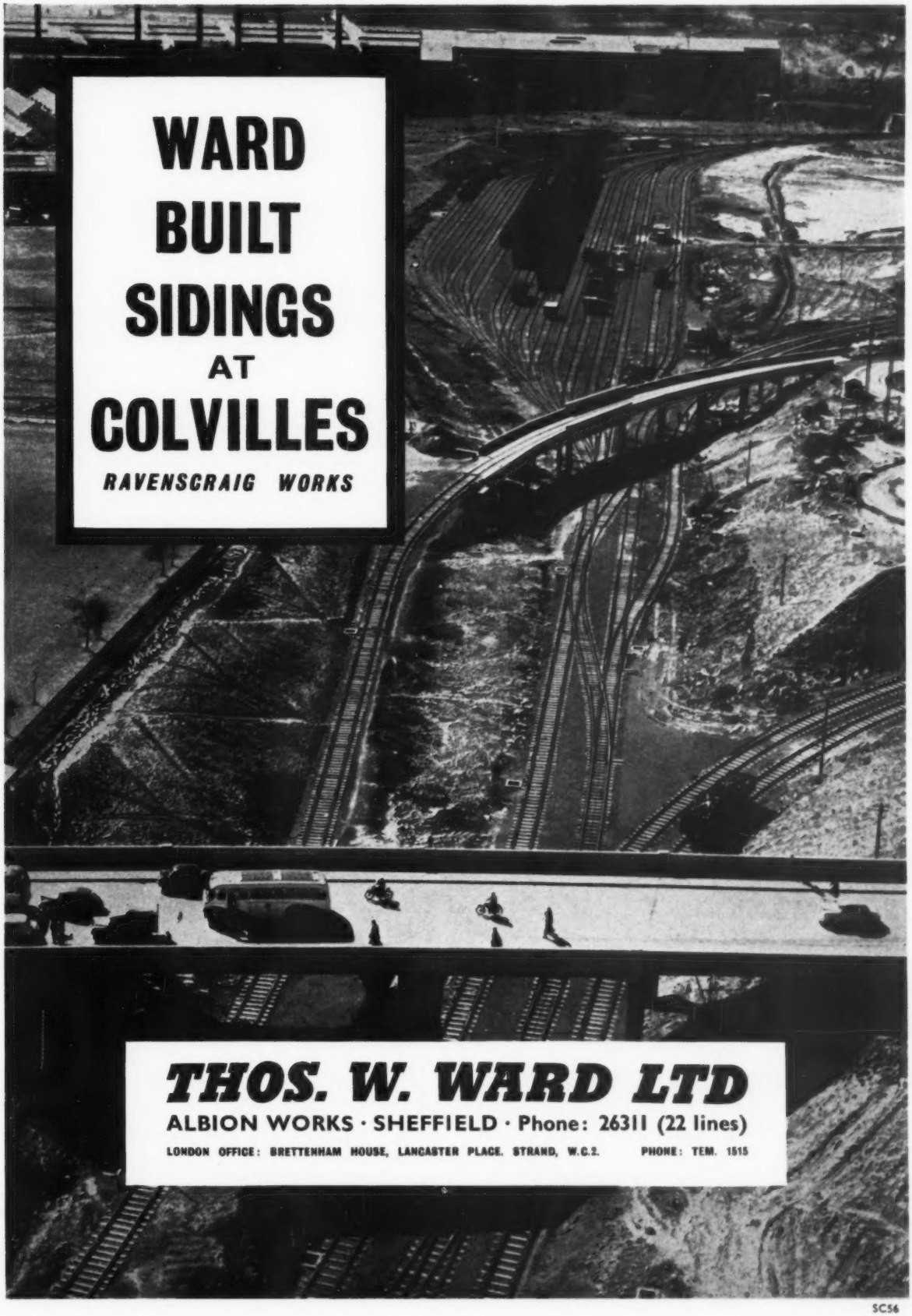
Enquiries to :—

UNITED COKE AND CHEMICALS COMPANY LIMITED
(SALES DEPARTMENT 252) P.O. Box 136, Handsworth, Sheffield 13.
Telephone : Woodhouse (Sheffield) 3211 *Telegrams : 'Unichem' Sheffield*

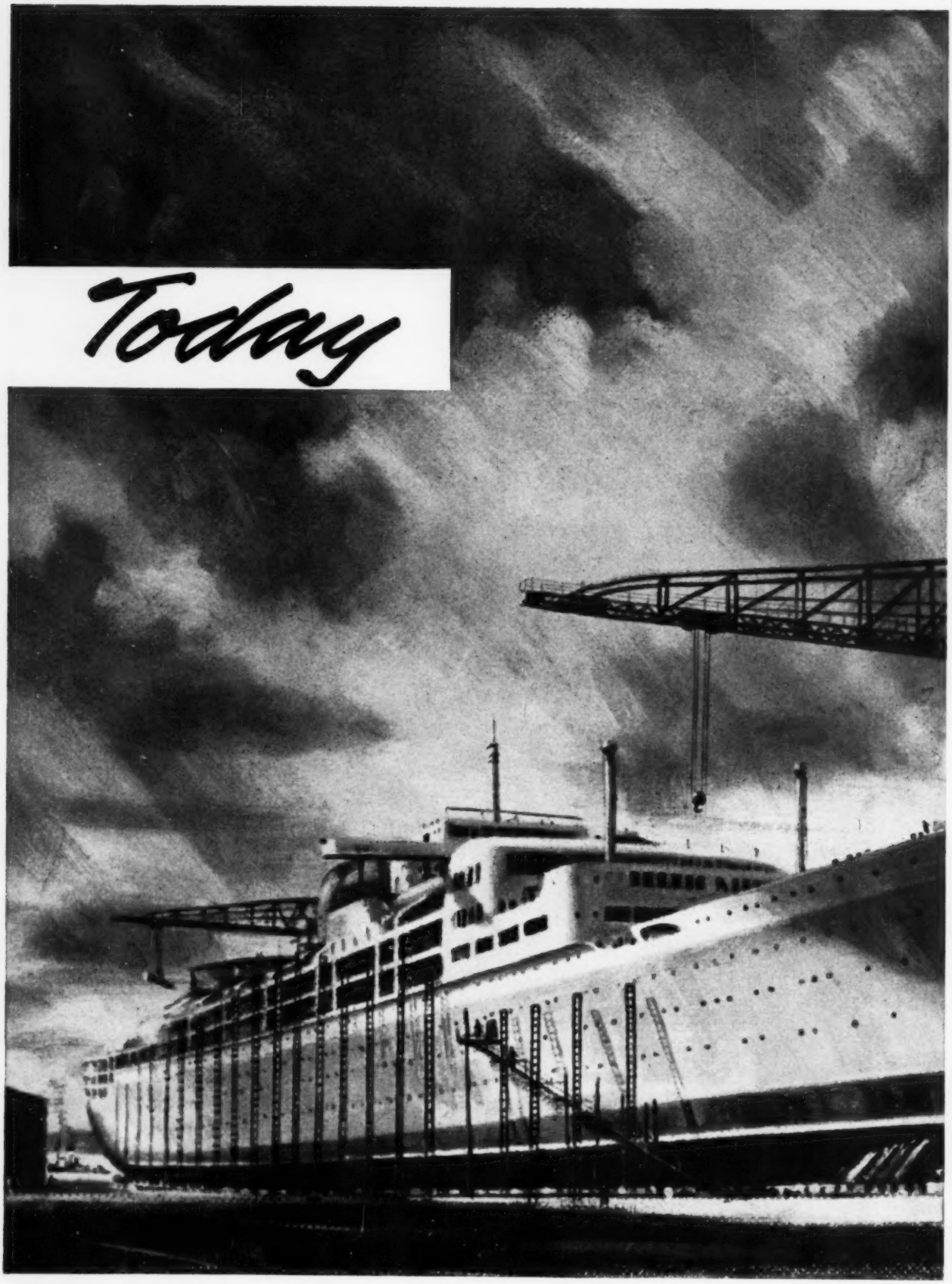
UCC
CHEMICALS FROM COAL

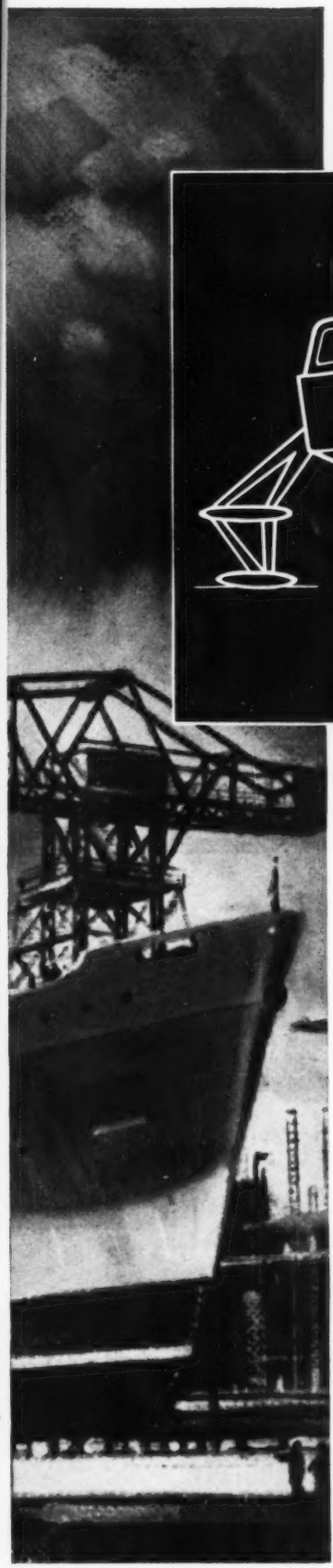
THE UNITED STEEL COMPANIES LTD

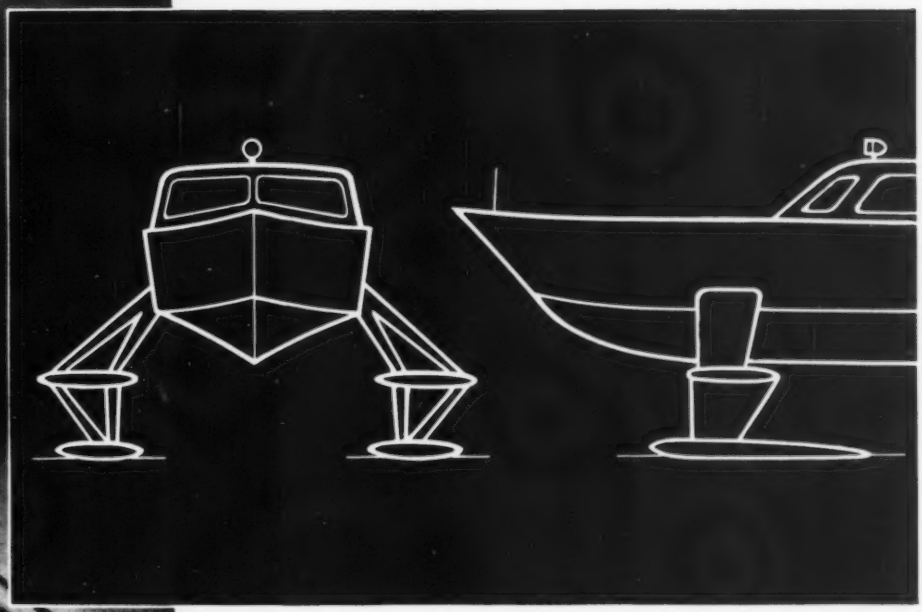
O2


WARD
BUILT
SIDINGS
AT
COLVILLES
RAVENSCRAIG WORKS
THOS. W. WARD LTD
ALBION WORKS · SHEFFIELD · Phone: 26311 (22 lines)
LONDON OFFICE: BRETTENHAM HOUSE, LANCASTER PLACE. STRAND, W.C.2. PHONE: TEM. 1515

SC56


Today



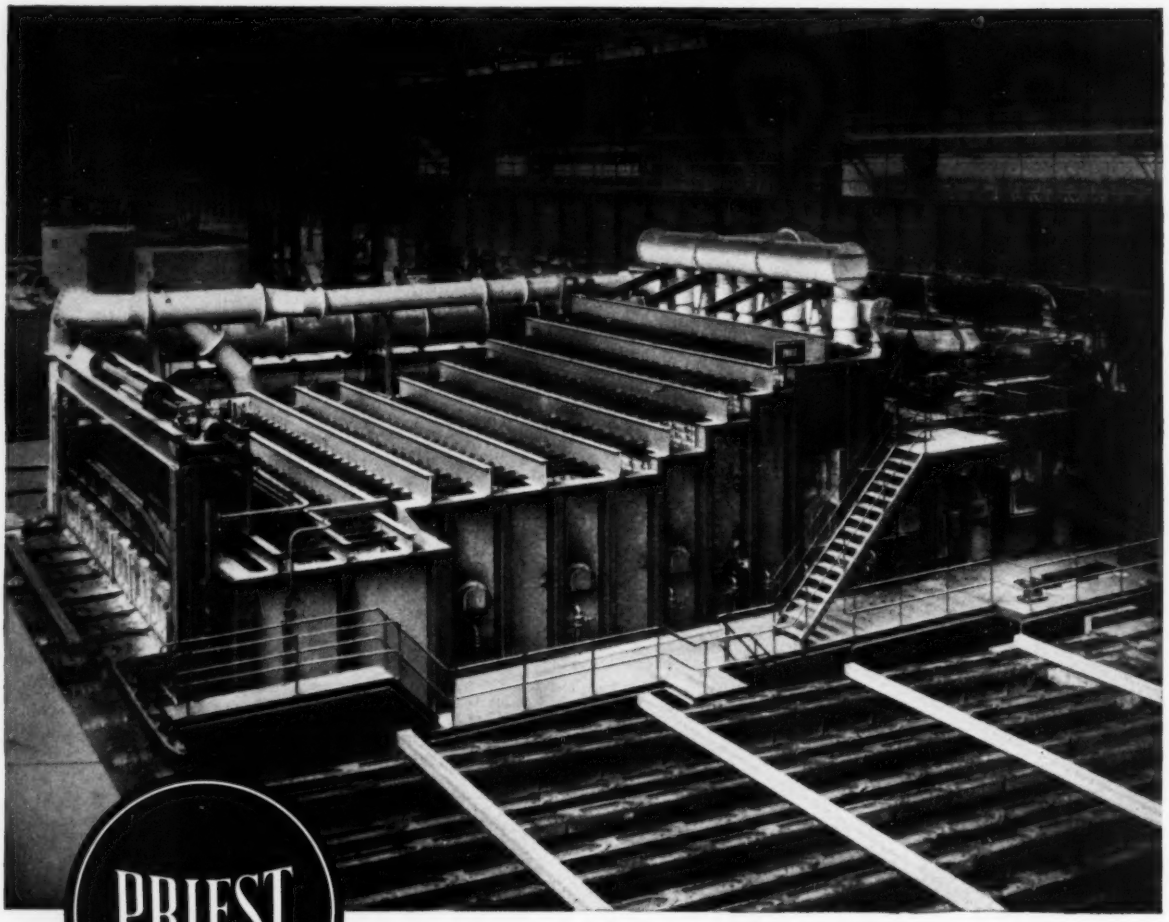


Tomorrow

Today gas is *the* fuel in forging, annealing, rivet heating and other basic heat processes in shipbuilding and heavy engineering; gas also has specialised applications such as drying before shot blasting. Industrial Gas research and consumer service ensure that tomorrow gas will be Britain's most economic fuel . . . **AND TODAY**— every industry and 12 million homes use **GAS.**

ISSUED BY THE GAS COUNCIL

A22/2Z



PRIEST

HEAVY BLOOM CONTINUOUS REHEATING FURNACE

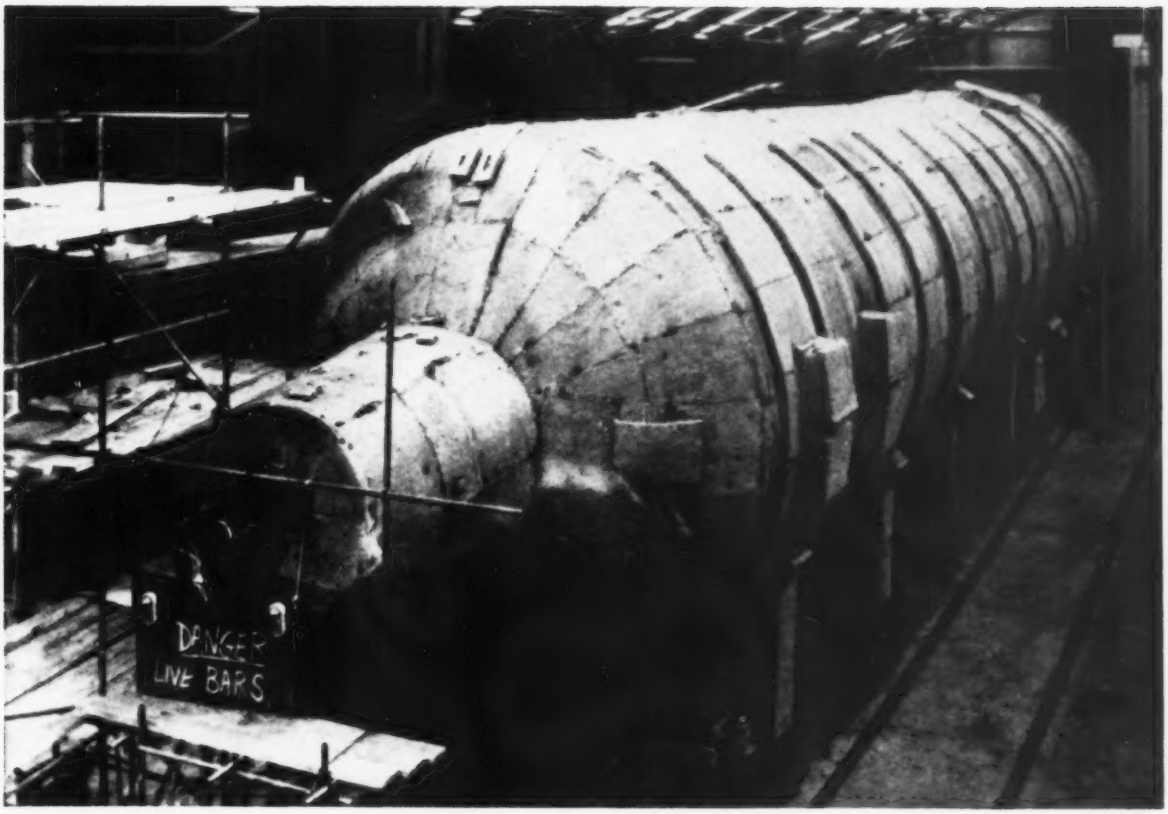
The above Furnace was supplied complete with electro-hydraulic pusher, recuperators and instruments and is capable of re-heating up to 80 tons per hour of cold blooms and part-formed sections.
Installed for the new Lackenby Beam Mill of Dorman Long (Steel) Limited.

We specialise in the design and construction of:—
Open Hearth Furnaces.
Soaking Pits of all types.
Continuous Multi-zone Bloom and Slab Re-heating Furnaces.
Continuous Bogie type Ingot and Slab Heating Furnaces.
Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating.
Forge and Heat Treatment Furnaces.
Stress Relieving Furnaces.
Shipyard Plate and Bar Furnaces.
Modern Lime Burning Kilns.

PRIEST FURNACES LIMITED · LONGLANDS · MIDDLESBROUGH
also at TELEGRAPH BUILDINGS HIGH STREET SHEFFIELD

PRIEST
The last word in Furnace design

F. 129



Stress relieving of a heat-exchanger for Bradwell Nuclear Power Station carried out at the Thornaby-on-Tees Works of Messrs. Head Wrightson, Teesdale Ltd.

Stress relieving of LARGE VESSELS

A MODERN TECHNIQUE

Above is an example of this technique. The 95 ft. long heat exchanger is totally covered with Stillite SR10 semi-rigid slabs and mineral wool mattresses. The heat is applied within the vessel by means of electric resistance elements disposed to give uniform heat. In this instance stress relieving temperature was attained in only *25 hours*, and the soaking temperature maintained.

ADVANTAGES

★ Stress relieving can be carried out on site thus solving the problem of transporting large vessels.

★ Saving in Capital Investment—no outlay required for a large permanent furnace structure.

★ Saving in heating costs. Relieving temperature quickly attained because of the low heat capacity of the enclosing insulation.

STILLITE

Regd. Trade Mark

Full information upon the application of this technique gladly sent on request.

STILLITE PRODUCTS LIMITED • 15 WHITEHALL, LONDON, S.W.1.

Telephone : Whitehall 0922/6 and 231 St. Vincent Street, Glasgow, C.2.

go

Fit as a fiddle, quick off the mark, he's away,
racing for the tape and success. His equipment? Natural aptitude,
trained muscles, good wind. *Your* god may be the ticker-tape,
your race an industrial one relying on technical achievement.
For that also you need good equipment, the finest materials. You must choose
carefully. If choice of a metal is your problem, we can help you.
Our metallurgists are always willing to advise on the use
of nickel and nickel-containing materials. Our laboratory
staff are testing and developing new materials all the time.
Let us help you win *your* race.

THE MOND NICKEL COMPANY LIMITED THAMES HOUSE MILLBANK LONDON SWI

TGA GN19

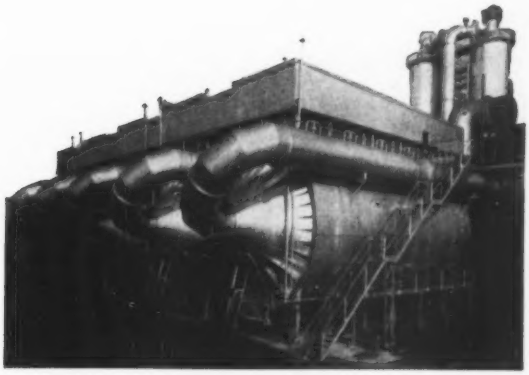


Photo Right: Close up of the five Precipitators installed by Lodge-Cottrell.

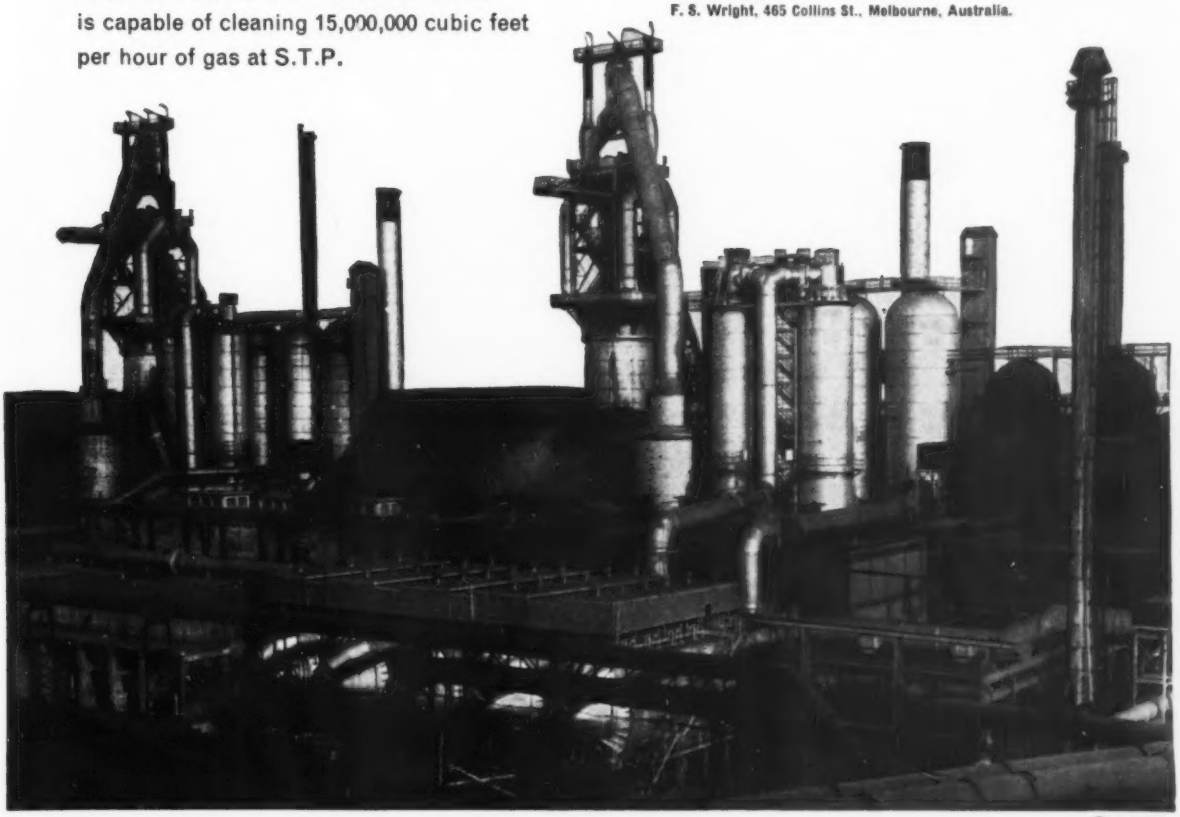
Photo Below: View looking towards 3 & 4 Blast Furnaces at Indian Iron and Steel Co's Works, Burnpur, India.

GAS CLEANING IN ASIA by Lodge-Cottrell

The competition for overseas contracts is as keen now as it has ever been. We are therefore glad to announce that a valuable contract to equip the Indian Iron and Steel Company's two new blast furnaces with four scrubber towers and five Electrofilters was completed on time before the end of 1958. The installation is capable of cleaning 15,000,000 cubic feet per hour of gas at S.T.P.

LODGE-COTTRELL LTD.
GEORGE ST., PARADE, BIRMINGHAM, 3.

Telephone: Birmingham CENtral 7714 (5 lines).
London: CENtral 5488.
OVERSEAS AGENTS: Continental Europe: Léon Bailly, Ingénieur Conseil, Avenue des Sorbiers, Anseremme-Dinant, Belgium.
SOUTH AFRICA:
Branch Office, 76 Magor House, 74 Fox St., Johannesburg, South Africa.
AUSTRALASIA:
F. S. Wright, 465 Collins St., Melbourne, Australia.



L.C.38.

CRAVEN
◀ 80 ton steelworks crane.
We are specialists in the design and manufacture of heavy duty and large capacity overhead electric travelling cranes.
Comprehensive catalogue forwarded on request
STEELWORKS CRANES

CRAVEN BROS. (Crane Division) LTD. LOUGHBOROUGH ENGLAND

A MEMBER OF THE MORRIS GROUP.

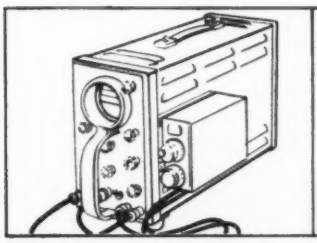
ULTRASONIC FLAW DETECTION

Choose your equipment from this new comprehensive range

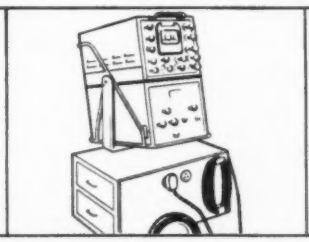
Kelvin Hughes ultrasonic flaw detection instruments and probes are available for all manual, semi-automatic and automatic testing techniques. High performance and versatility are obtainable with this comprehensive range of competitively priced equipment designed for laboratory work as well as routine inspection schedules. Auxiliary units include Automatic Flaw Alarms, Depth Gauges, Probe Holders and Manipulators.

ULTRASONIC FLAW DETECTOR Mk. 6

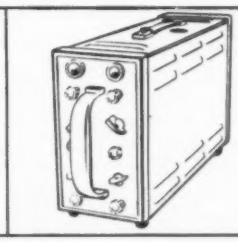
This powerful, versatile instrument has an exceptionally wide operating frequency range, and a variety of controls enabling particular methods of tests to be devised. The trolley mounted display and control units are readily adjustable to the most convenient position. A brilliant trace is given over the full width of a 6 in. C.R.T. Operates with single, twin or separate probes for contact, gap or immersion scanning. Automatic flaw alarm circuits, depth gauge and photographic recording facilities can be added.



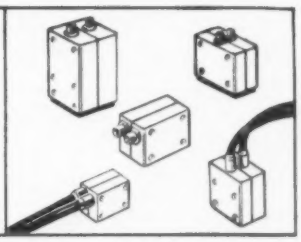
Flaw Detectors Marks 5F, 5AF. *Portable instruments with similar basic specifications. The 5F is a multi-frequency instrument for use with twin or separate type probes, whilst the 5AF, a single frequency instrument, either 1½, 2½ or 5 Mc/s. Also operates with single type probes. (Shown with Depth Gauge attachment).*



Flaw Detector Mark 6. *Trolley mounted transportable equipment, very powerful and versatile for use with all types of probes and having an exceptionally wide frequency range and high sensitivity.*



Two Channel Flaw Alarm. *For use with Mark 5 instruments, a portable auxiliary unit providing semi-automatic monitoring facilities which identify and give warning of significant defects.*



Probes. *Extensive development by Kelvin Hughes has resulted in a range of standard probes having either single, twin or separate transducers, and a very high performance throughout.*

AUXILIARY EQUIPMENT

Includes a Depth Gauge for use with all instruments and which will measure thicknesses between 0.1 to 4 ins. with an accuracy of 0.75%, Probe Holders with irrigation facilities for large surface scanning, and remote Probe Manipulators.

KELVIN HUGHES

KELVIN & HUGHES (INDUSTRIAL) LIMITED

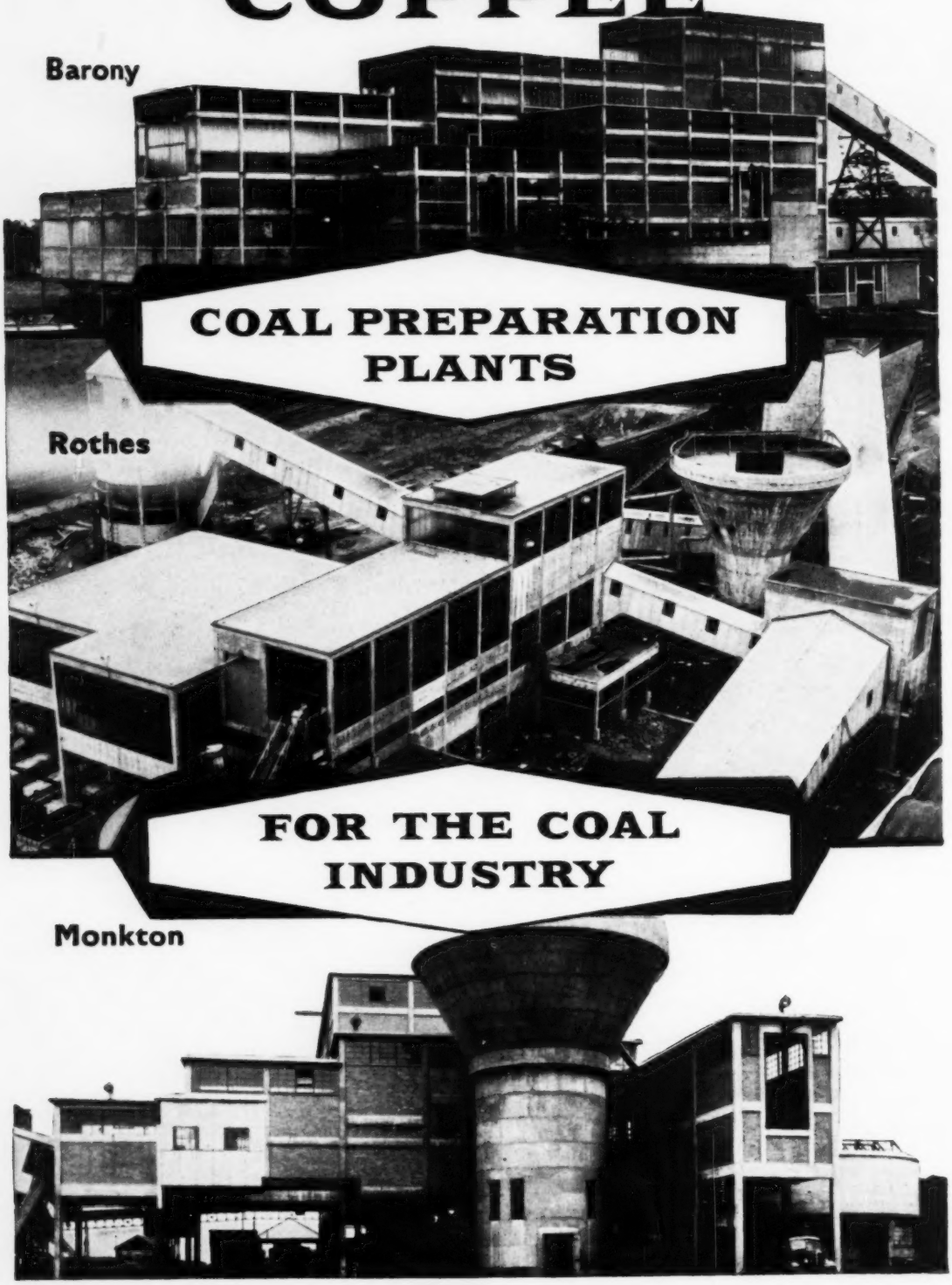
Kelvin House, Wembley Park Drive, Wembley, Middlesex

60-72 Kelvin Avenue, Hillington, Glasgow, SW2

KH92

COPPEE

Barony



Please write for further details to:

THE COPPEE COMPANY

COPPEE HOUSE · 140 PICCADILLY

LONDON W.1 Telephone: HYDe Park 6801

(GREAT BRITAIN) LIMITED

Telegrams: EVCOPPEE, NORPHONE, LONDON

GLASGOW: 121 DOUGLAS STREET, C.2

NEWCASTLE-ON-TYNE: MANSION HOUSE CHAMBERS, THE CLOSE

BRITISH STEEL AT ITS BEST

WE PRODUCE

BASIC OPEN HEARTH STEEL

QUALITIES

CARBONS UP TO 1.0%
DEEP STAMPING & RIMMING
SILICON & SILICO-MANGANESE
FREECUTTING
LEAD-BEARING

SIZES

BLOOMS	5″ up to 9″ square
BILLETS	2″, 2¼″, 2½″, 3″, 3½″ and 4″ sq.
SLABS	5″ to 16″ wide x 2″ to 2½″ thick
SHEETBAR	12″ wide x ¼″ to ¾″ thick

Other sizes by request

Telegrams : 'Lysaght-Scunthorpe'
Telephone : 2271 (5 lines)

For further particulars please write to us at :
JOHN LYSAGHT'S SCUNTHORPE WORKS LTD.,
Normanby Park Steel Works,
SCUNTHORPE, Lincolnshire.

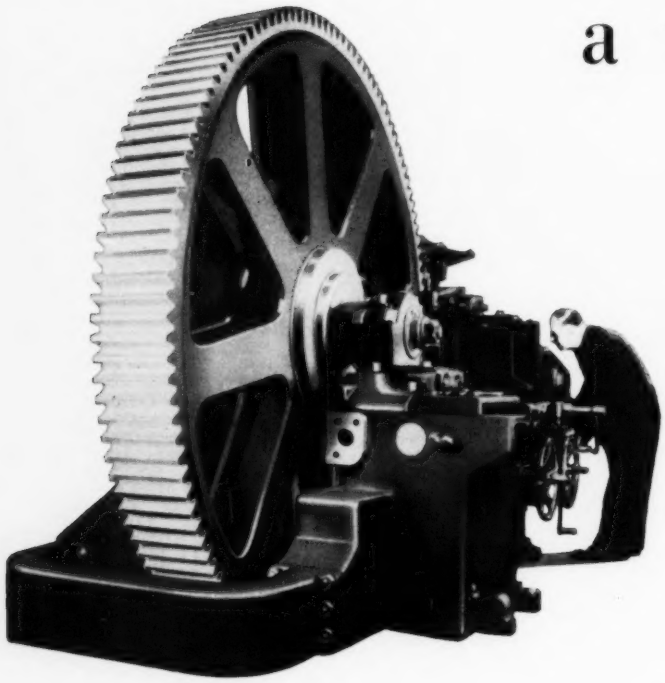
LYSAGHT'S SCUNTHORPE

Adamson-Alliance equipment for the steel industry

ADAMSON-ALLIANCE CO. LTD.

ROSS

Wherever power is used Crofts Gearing plays a vital role



• SPUR GEARS

up to 185″ diameter
up to 32″ face width
up to 5″ CP

Send for Publication 159

CROFTS MACHINE-CUT GEARS

- **Full Stock range: Spurs up to 70 h.p., Bevels up to 44 h.p., Mitres up to 70 h.p. Larger sizes available at short notice. Worms up to 12″ diameter, 3″ normal pitch; Wheels up to 102″ diameter, 3″ normal pitch; Internals up to 96″ outer diameter, 6″ face 20 DP. to 1½ DP.; Racks and pinions up to 5″ pitch, any length.**
- **Double Helicals up to 185″ diameter, 32″ face width, 5″ CP. Single Helicals up to 185″ diameter, 27″ face width (at 15° helix angle), 1 DP. larger face widths possible for smaller helix angles.**
- **Spiral Bevels and Mitres up to 60″ diameter; Straight-faced Bevels and Mitres up to 72″ diameter, 14″ face width, 4″ CP.**

CROFTS (ENGINEERS) LIMITED

POWER TRANSMISSION ENGINEERS

Head Office:
THORNBURY · BRADFORD 3 · YORKSHIRE
Phone: 65251 (20 lines) Telegrams: 'Crofters Bradford Telex' Telex 51186

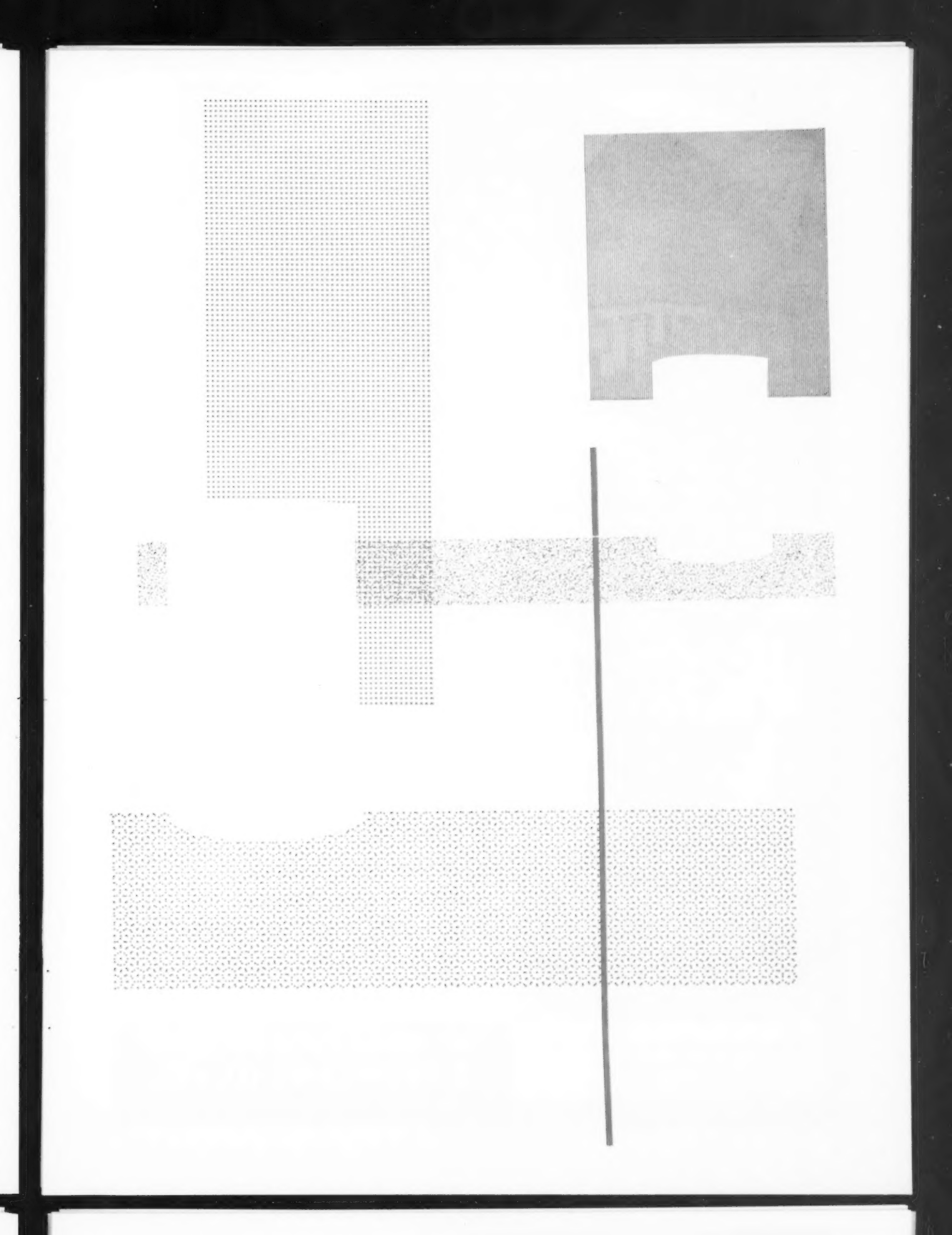
Branches at:
Belfast, Birmingham, Bristol, Cardiff, Dublin, Glasgow, Ipswich, Leeds, Liverpool, London, Manchester, Newcastle, Northampton, Nottingham, Sheffield, Stoke-on-Trent.
Subsidiary Companies in Canada, South Africa, U.S.A. Representation throughout the world.

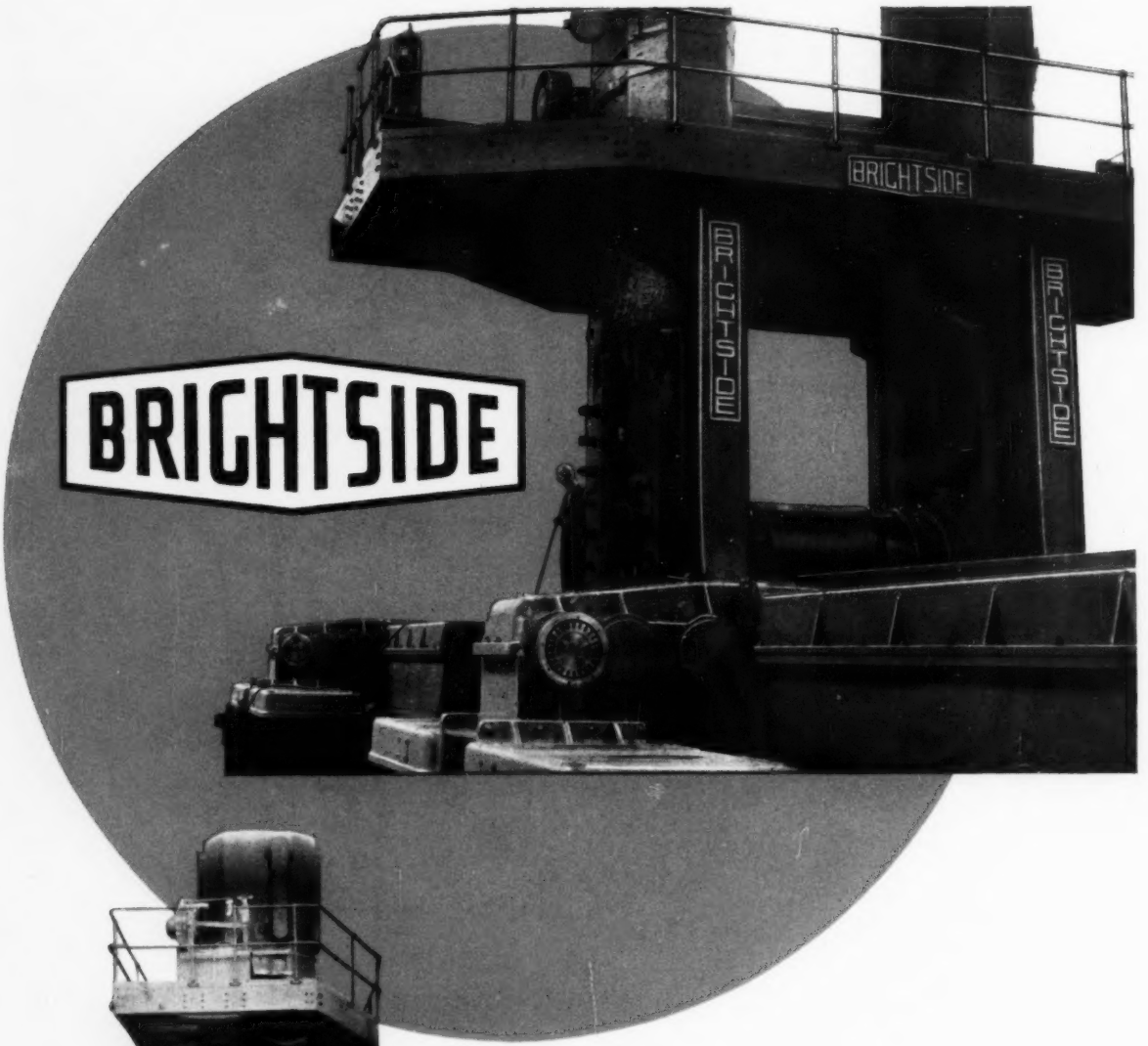
TEXOLEX MILL BEARINGS

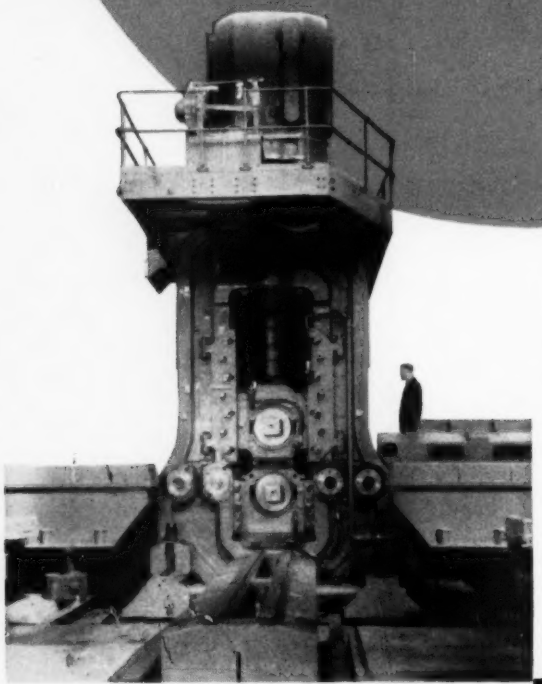
THE BUSHING COMPANY LTD. HEBBURN ON TYNE

TELEPHONE: HEBBURN 83-2241 • TELEGRAMS BUSHING HEBBURN

CX







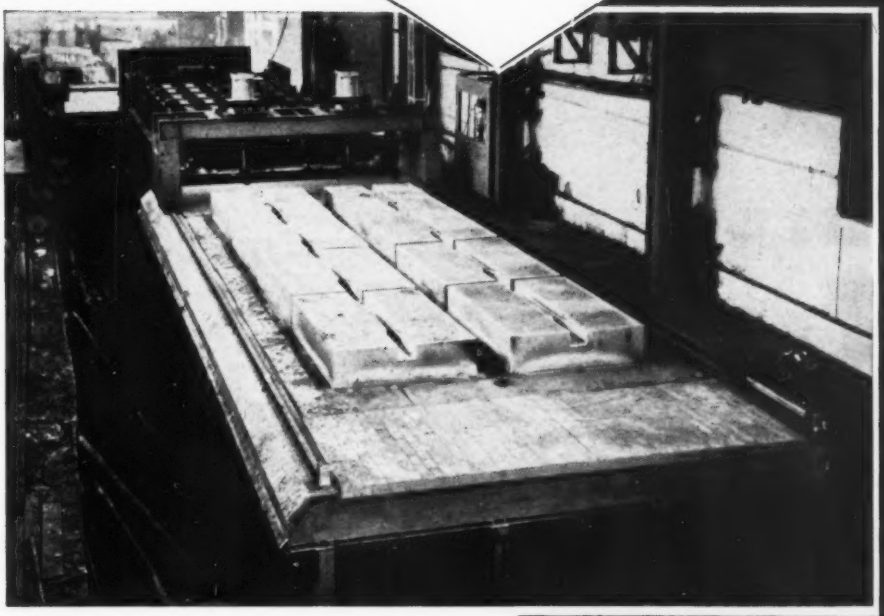
34" dia. x 84" Slabbing and Blooming Mill. Shop erection photographs.

HOT AND COLD ROLLING MILLS.
ROLLS FOR HOT AND COLD ROLLING.
ROLL LATHES.
HOT AND COLD SHEARS.
HOT SAWS AND REELERS.
STEELWORKS PLANT AND AUXILIARIES.

THE BRIGHTSIDE FOUNDRY & ENGINEERING CO. LTD.
SHEFFIELD 1. G.P.O. BOX 118

One of the many installations using KIP

LIGHTWEIGHT INSULATING REFRACTORIES



Photograph reproduced by courtesy of Appleby — Frodingham Steel Company (Branch of The United Steel Companies, Ltd.) and Stein and Atkinson, Ltd.

Electric soaking pit, designed and built by Stein and Atkinson Ltd., for the Appleby—Frodingham Steel Company (Branch of the United Steel Companies Ltd.), Scunthorpe

KINGSCLIFFE
INSULATING PRODUCTS LTD.

STORRS BRIDGE WORKS, LOXLEY, SHEFFIELD
Phone: 343844/5

KIP/30.

LANCASHIRE STEEL

WIRE RODS
IN ALL QUALITIES

JOISTS ANGLES
CHANNELS TEES

FLATS ROUNDS

HOT & COLD
ROLLED HOOPS
CABLE TAPE

OTHER PRODUCTS

BASIC PIG IRON FERRO-MANGANESE
SASH & CASEMENT SECTIONS SQUARES
HAMMER LOCK STRUTS TUBE STEEL
IRON, STEEL & NON-FERROUS CASTINGS
COKE OVEN BY-PRODUCTS
CONCRETE FLAGS ETC.

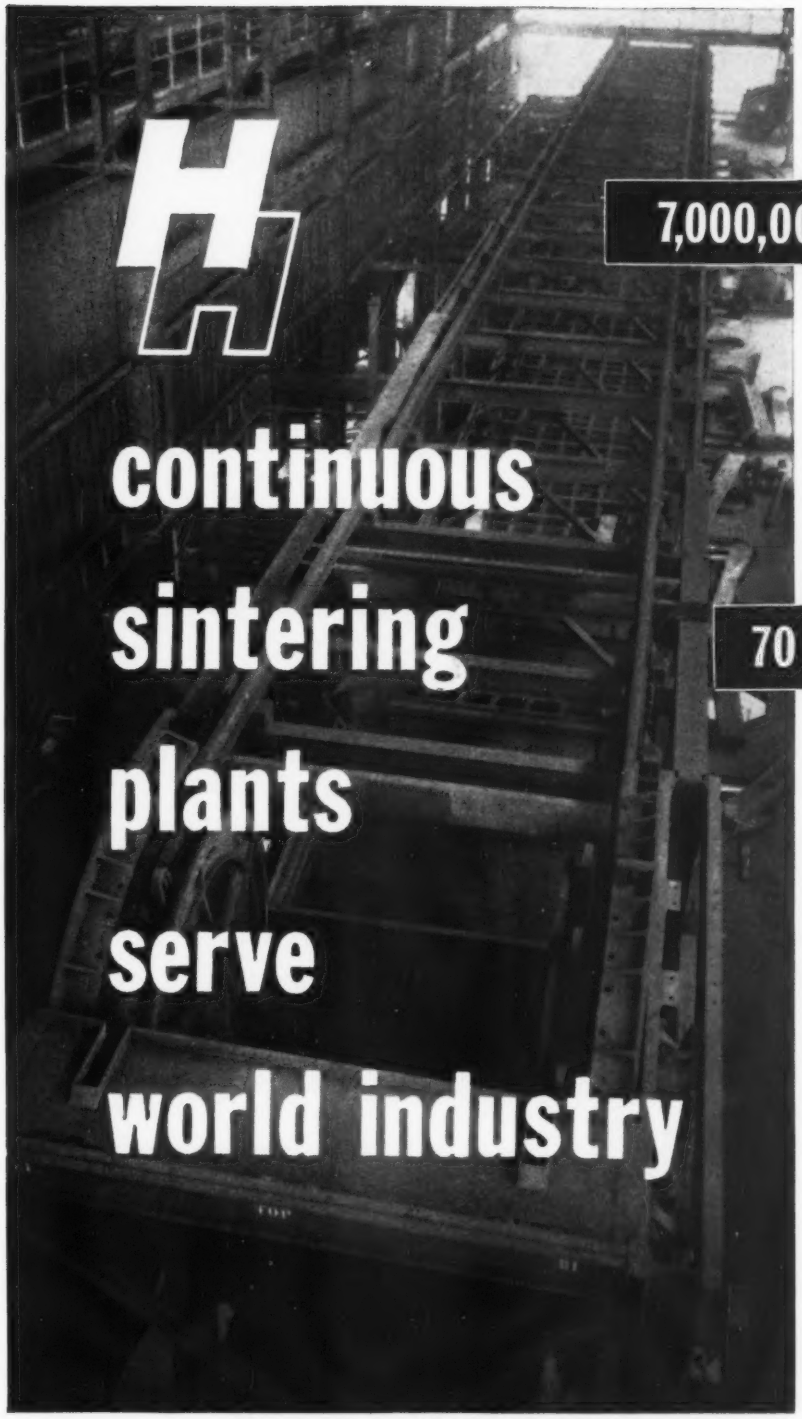
LANCASHIRE STEEL MANUFACTURING COMPANY
LIMITED
(HEAD OFFICE:)

Telephone: 31222

WARRINGTON
WORKS: IRLAM & WARRINGTON

Telegrams: LANCASTEEL

London Office: KINNAIRD HOUSE, PALL MALL EAST, S.W.1 · *Telephone:* WHITEHALL 7515 · *Telegrams:* LANCASTEEL, LESQUARE, LONDON



A Huntington Heberlein sintering plant under construction

7,000,000 tons per year

Seven million tons of sinter per annum is the impressive aggregate output of the fifteen sinter plants ordered by iron and steelworks at home and abroad from Huntington Heberlein since the beginning of 1955.

70 years' experience

Behind the design of these plants, in Britain, France, Belgium and South Africa, is some seventy years' experience of the sintering process which is coupled with an up-to-date knowledge of the latest techniques and potentialities of the process.

ASSOCIATED IN THE U.S.A. WITH KOPPERS COMPANY INCORPORATED

Other specialities include:
Ore Dressing Plants, High Intensity Magnetic Separators, Herreshoff Furnaces, Badische Turbulent Layer Roasters.

Continuous sintering plants by

Huntington, Heberlein & Co. Ltd

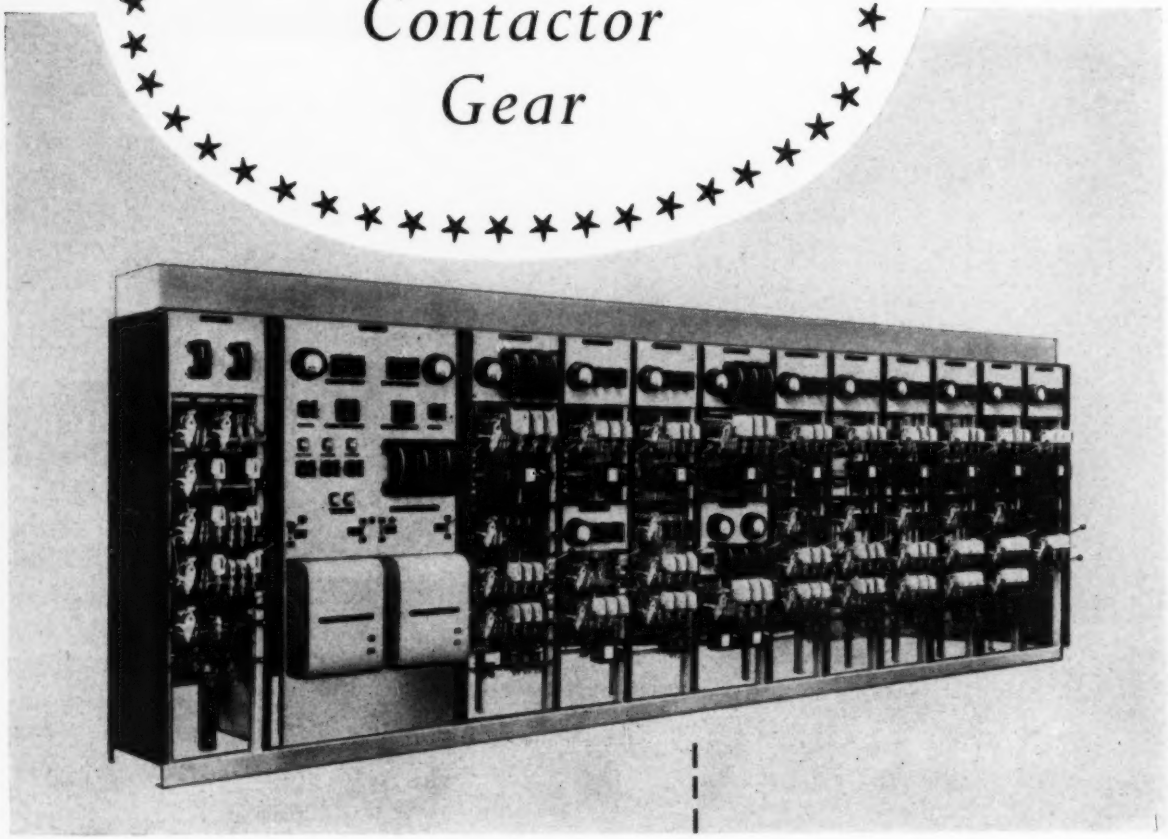
SIMON ENGINEERING GROUP

SIMON HOUSE, 28-29 DOVER STREET, LONDON, W.1. Telephone: Hyde Park 8191. Telex: 2-3165. Telegrams: Innovation Wesphone London Telex

COMMONWEALTH REPRESENTATIVES | Simon-Carves (Africa) (Pty) Ltd: Johannesburg Simon-Carves (Australia) Pty Ltd: Botany, N.S.W.

HH22

Steel Works Contactor Gear



One of the many control boards together with control desks supplied to The Steel Company of Wales Limited for the Coiling, Cut up and Finishing Lines at their Abbey Works.

Contactor Switchgear Limited manufacture automatic electric control gear (up to 6,600v. A.C. and 650v. D.C.) for Power Station Auxiliaries, Steel Works, Water Works, Rolling Mills, Sewage Works, Chemical Plants, Gas Works and Cement Works, including Cranes, Electric Furnaces, Machine Tools, Fans and Pumps.

May we have *your* enquiries for steel works automatic control gear?

CONTACTOR SWITCHGEAR LTD
WOLVERHAMPTON
ENGLAND

CONTACTOR SWITCHGEAR LTD.

BLAKENHALL · WOLVERHAMPTON · ENGLAND

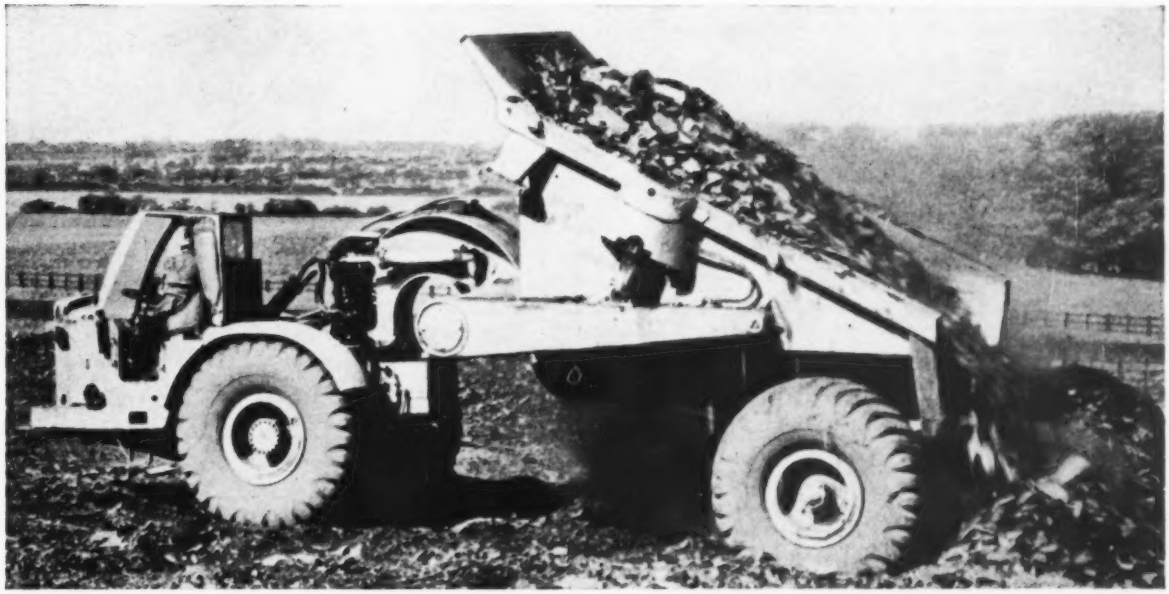
Telephone: Wolverhampton 25911/7 *Telegrams: TACTORGEAR Wolverhampton*

COR-TEN IS STILL NEWS

In 1954, for the first time in Britain on a wide continuous strip mill, The Steel Company of Wales began the manufacture of SCW Cor-Ten.

Today, four years later, the range of application for SCW Cor-Ten continues to grow as more designers and more users discover new ways in which they can take advantage of its outstanding properties.

Photograph by courtesy of Caterpillar Tractor Company Ltd.



Wherever higher strength or greater resistance to atmospheric corrosion offer economic advantages, SCW Cor-Ten *has been used. Where corrosion and abrasion are both present (as in the case above)* SCW Cor-Ten's *outstanding advantages are particularly effective.*

COR-TEN IS TOUGHER

- Weight for weight, the yield strength of SCW Cor-Ten is 50% higher than ordinary mild steel
  alternatively
  Strength for strength, a saving of ⅓ of the weight is possible
- 4-6 times more resistant to atmospheric corrosion
- Highly resistant to abrasion and fatigue.

COR-TEN SAVES MONEY

- Initial costs are spread over a longer service life
- Maintenance costs are reduced
- Operating costs are lowered—in transport applications payloads are bigger because of reduction in tare weight

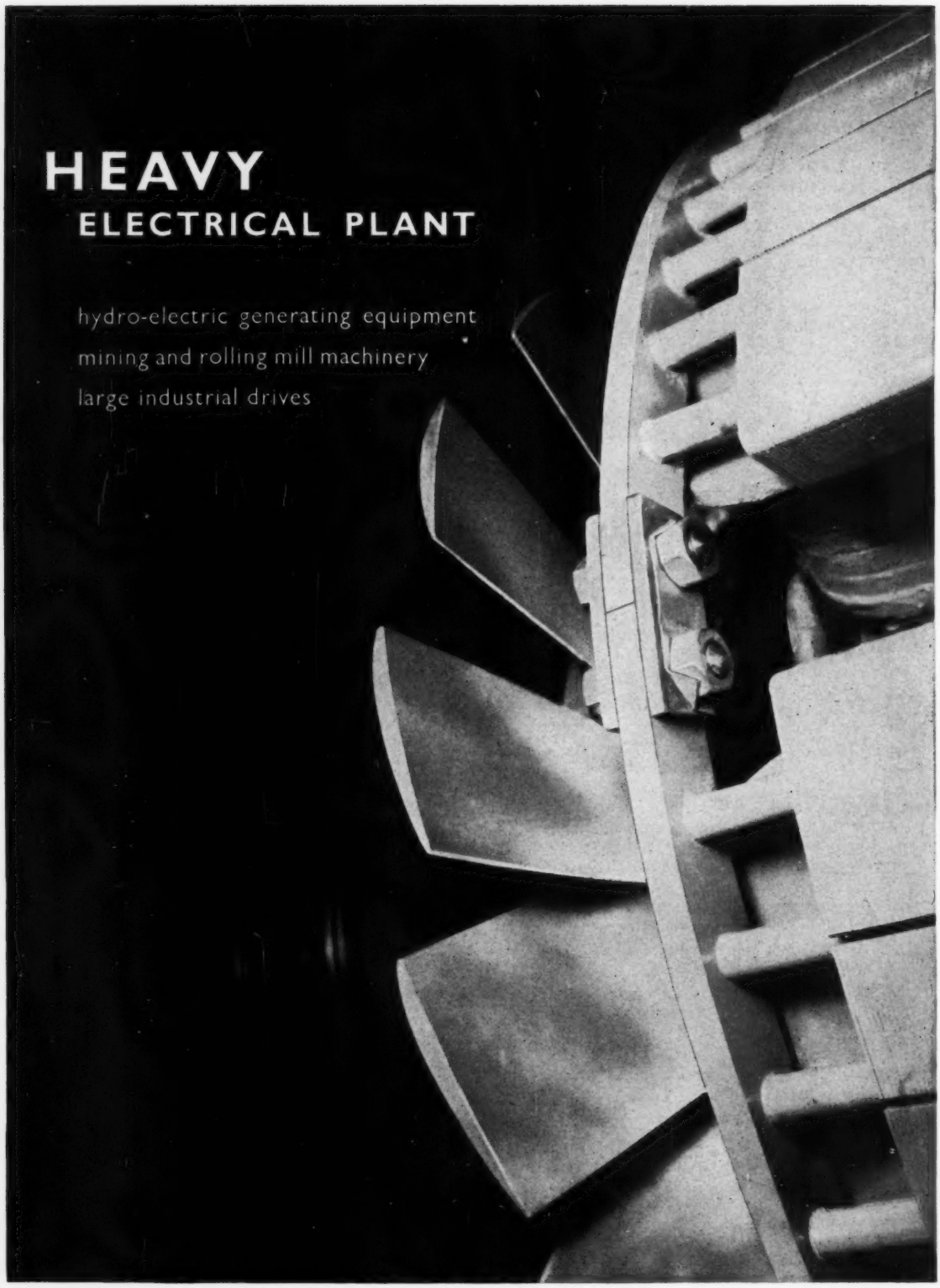
Please write to us at the address below for further information or for technical assistance in the application of SCW Cor-Ten *to your products*

S·C·W BRAND
Cor-Ten

RAILWAY ROLLING STOCK
AGRICULTURAL AND EARTH-MOVING EQUIPMENT
MINE CARS · POWER STATION INSTALLATIONS
BARGES AND SMALL CRAFT

THE STEEL COMPANY OF WALES LIMITED

ABBEY WORKS, PORT TALBOT, GLAMORGAN TELEPHONE: PORT TALBOT 3161

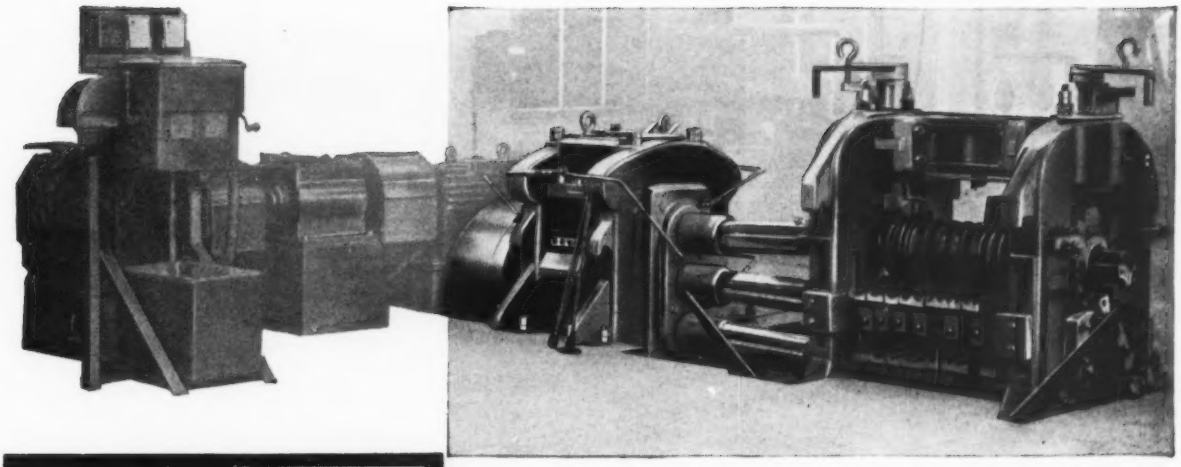


A·E·I **HEAVY PLANT DIVISION**

RUGBY & MANCHESTER, ENGLAND

A DIVISION OF ASSOCIATED ELECTRICAL INDUSTRIES LTD., incorporating the interests of **BTH & M-V**

A 5356

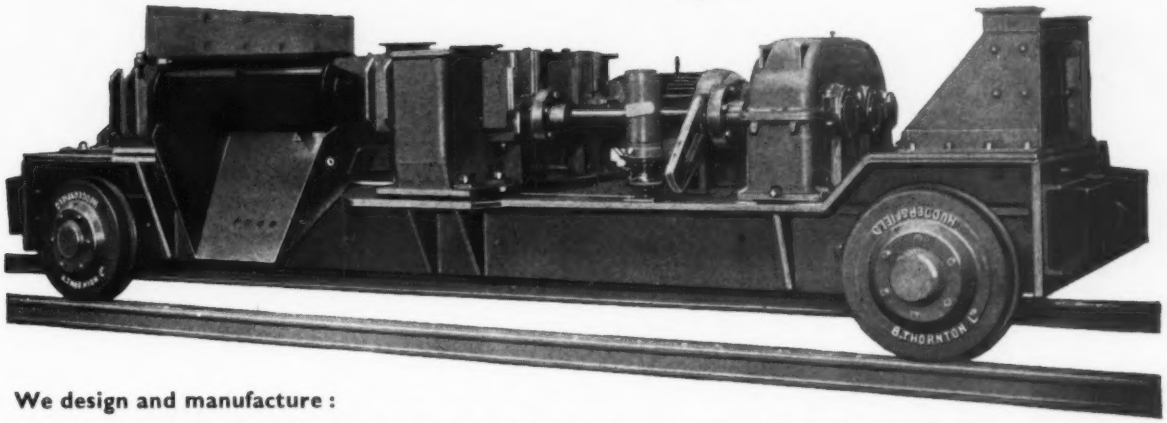


Thornton

12" Mill as supplied to Swinden Laboratories, Rotherham, and published by courtesy of The United Steel Companies Ltd.

Engineers and Contractors

Ingot Transfer Car for conveying 4/5 ton Ingots.



We design and manufacture :

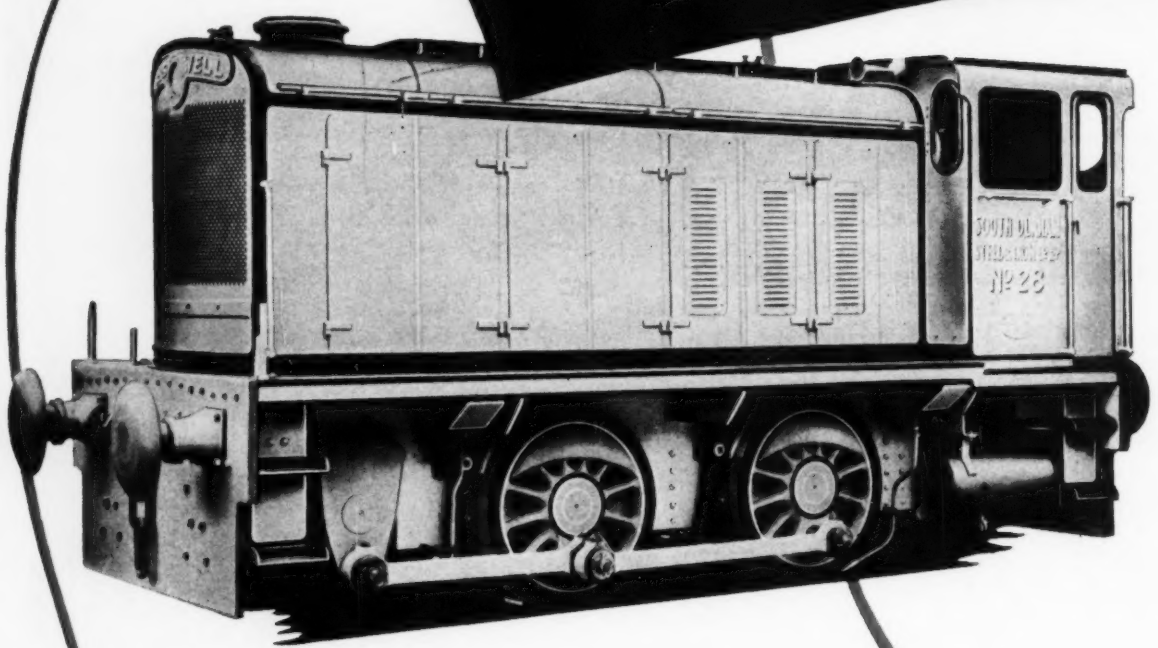
Equipment for Coke Ovens, Blast Furnaces and Open Hearth Plant.
Rolling Mills for the Ferrous and Non-Ferrous Industries and Rolling Mill auxiliaries.
Plate Work. Bogies of all kinds for carrying light or heavy loads.
General Engineering work of various kinds.

We shall be glad to quote against your requirements and specifications

B. THORNTON LIMITED

Turnbridge, Huddersfield. Phone. Huddersfield 7541

British Engineering at its best



260 B.H.P. Diesel Mechanical Locomotive

for the South Durham Steel & Iron Co. Ltd.

Incorporating National Diesel Engine, Scoop Control

Fluid Coupling, S.S.S. 3-speed Powerflow Gear Box.

HUDSWELL, CLARKE
AND COMPANY LIMITED

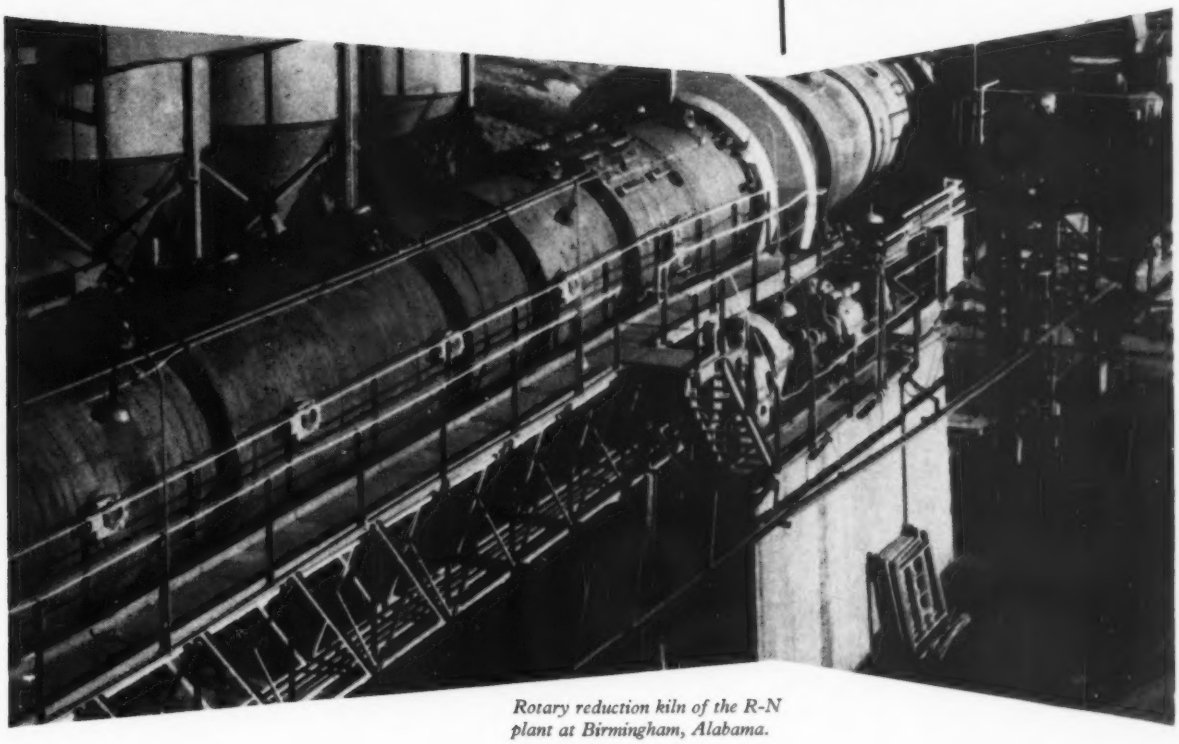
Pioneers for nearly 100 years

DESIGNERS AND BUILDERS OF STEAM, DIESEL MECHANICAL, DIESEL ELECTRIC, ELECTRIC AND BATTERY LOCOMOTIVES FOR ALL PURPOSES

Locomotive Engineers, Railway Foundry, Leeds, 10
Telephone: 34771 (6 lines) Cables: Loco, Leeds
London Office: 120/122 Victoria Street, S.W.1. (Telephone: VICtoria 6786)
Telegrams: Hudclar, Sowest, London. Cables: Hudclar, London.

THE R-N PROCESS

for direct reduction of iron ore and subsequent wet separation of gangue



Rotary reduction kiln of the R-N plant at Birmingham, Alabama.

R-N Product replaces pig iron as well as scrap

The R-N Process provides the world's steel industry with a new steel furnace feed material from ores of nearly all types by direct reduction utilizing various types of solid, low-cost fuel and surplus gas if available.

The wet magnetic separation after reduction removes the ore gangue and the concentrate obtained contains usually more than 90% Fe as metal, less than 3% SiO_2 and only a smaller part of the phosphorus of the ore.

The sulphur content of the concentrate is below 0.05%.

The concentrate is dried and formed into briquettes.

The capital cost of an R-N plant is about half that required for a blast furnace complex of corresponding size, and the production cost for R-N metallic iron briquettes will be considerably lower than that for pig iron.

Low stable price and uniform composition make R-N iron an excellent and competitive substitute for scrap.

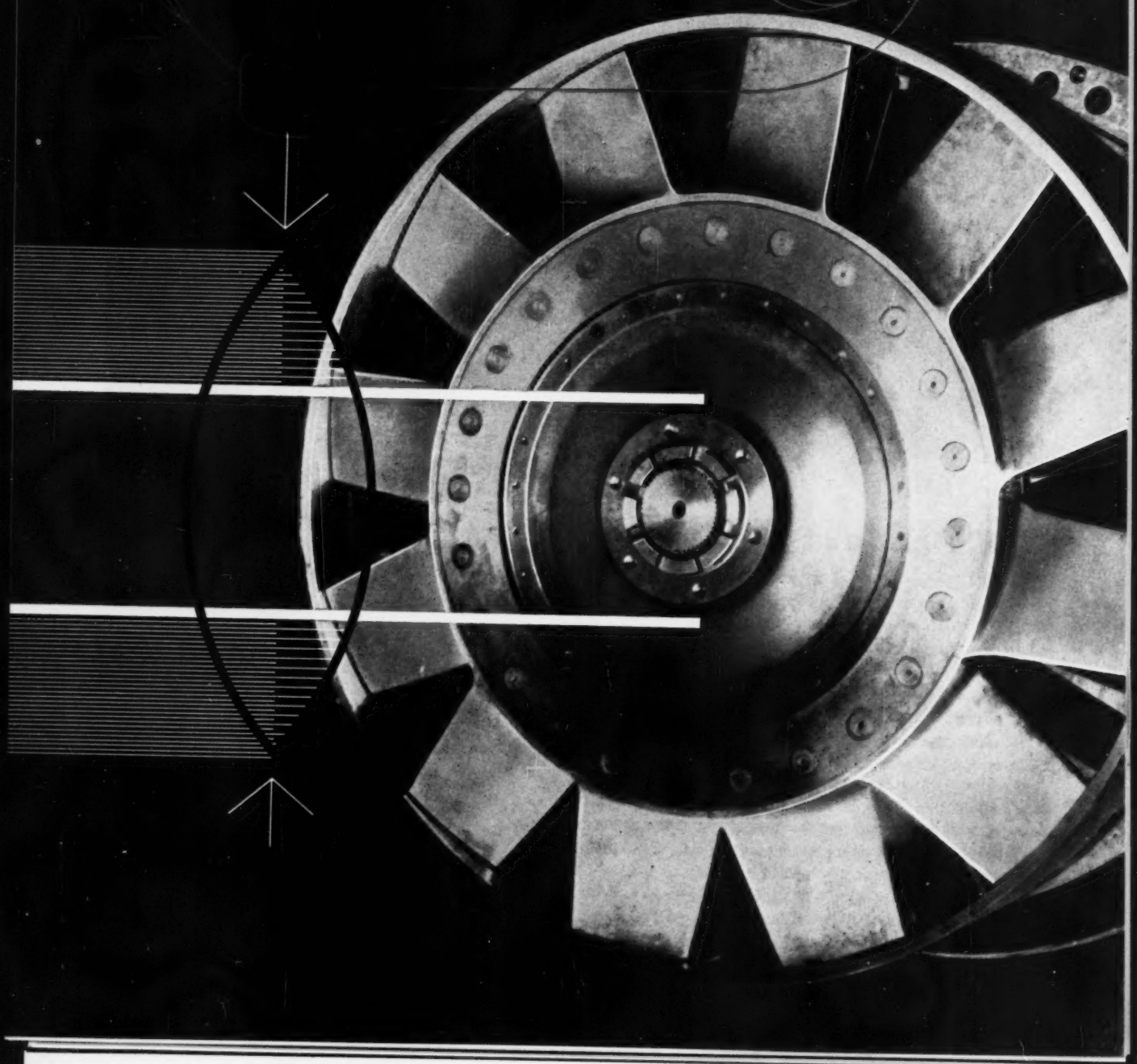
The development of the R-N process to a commercial process is the result of collaboration between the Republic Steel Corporation and the National Lead Company through the R-N Corporation, New York.

Representative for Europe:

R-N PROCESS AGENCY

162, Avenue Louise,
Brussels.

APL blower oil on



sentry-go at Bradwell...

The crucial points of the high pressure CO_2 coolant circuit at Bradwell will be the blower shaft seals. Every minute of every working day Shell APL blower oil will guard these escape points—being continually pumped into the seals and bearings, led away, purified and recirculated.

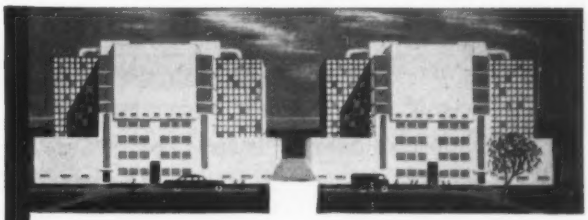
This very remarkable oil presents a two-way seal. Outwards, there is a minimum CO_2 loss as the oil has the lowest possible gas solubility. Inwards, in spite of the heat of the gas, oil vapour contamination is negligible thanks to the extremely low vapour pressure of the oil.

The research that went into APL blower oil is characteristic of the way Shell set about doing things. It was conducted at Shell's Research Centre at Thornton in close collaboration with the U.K. A.E.A. and the blower manufacturers. In the course of much fundamental research, a wide range of oils was subjected to vapour pressure and gas solubility tests in the laboratory. Selected oils from this range were used in the bearings and seals of a blower rig. In 1956, after four years of research, the finished product joined the Shell Atomic Power Lubricants range—marketed under the name of Shell APL 729. This oil has been in use at Calder Hall since the autumn of 1956.

The moral of the story is that Shell research is supremely applicational. The Centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubrication problem it pays to get in touch with your local distributor of Shell Industrial Lubricants.

The Research Story

Though the sealing action demanded of Shell blower oil is common in other industrial equipment such as hydrogen-cooled alternators, there were quite a few additional problems. It was necessary for the oil to have long life, low vapour pressure, low gas solubility, good thermal stability and high film strength —to be able to withstand high temperatures and to be resistant to all kinds of corrosive influences, including carbonic acid. The crux of the research was to combine all the above requirements into one oil, in order to minimise back diffusion of molecules which would contaminate the reactor.



BRADWELL NUCLEAR POWER STATION, AN ARTIST'S IMPRESSION.

SHELL

ATOMIC POWER LUBRICANTS

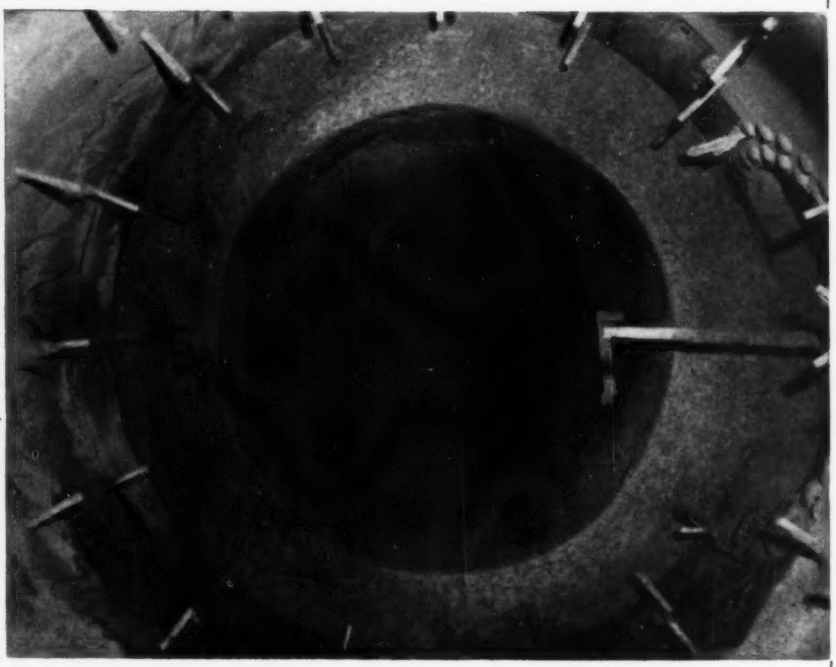
another proof of Shell leadership in lubrication

THIS IS _____ ? _____

1 . . . AN EXTENSION TO THE LONDON UNDERGROUND

2 . . . THE BUSTLE MAIN OF A BLAST FURNACE

3 . . . THE INLET PIPE OF A HYDRO-ELECTRIC POWER STATION



Number two is the answer. It is in fact the bustle-main of the Queen Victoria blast furnace at Appleby-Frodingham in course of being lined with Tri-Mor 'Guncrete'. The main is 5 ft. in diameter and the 'Guncrete' lining 9" thick. This is a far quicker and cheaper form of lining for a hot-gas main than brickwork. After twelve months continuous service this lining is still in perfect condition. Brick-lined mains usually require considerable repair after this period.

Tri-Mor 'Guncrete' is one of a series of new mouldable and castable refractories which are reducing first costs *and* maintenance costs in every kind of furnace from forging furnaces to ships' boilers. The most useful of these refractories are: - - - - - - - - - - - ▸

TRI-MOR *Standard Castable*
TRI-MOR *High Strength Castable*
TRI-MOR *High Temperature Castable*
TRI-MOR *High Temperature Mouldable*
TRI-MOR *Dense 'Guncrete'*
TRI-MOR *Insulating Castable*
TRI-MOR *Insulating 'Guncrete'*

MORGAN Refractories Ltd

MORGAN REFRACTORIES LIMITED, NESTON, WIRRAL, CHESHIRE. TELEPHONE: NESTON 1406

NE 144A

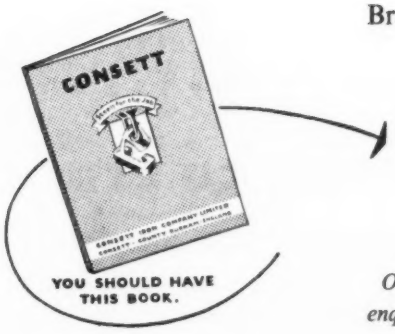
Dutch Print, circa 1610, depicting the craft of the "Locksmith" from Book of Engravings Vol. III by Jan Van Vliet, British Museum.

Copyright, Radio Times Hulton Picture Library

Every man to his own trade –

and our trade is STEEL!

Not only mild steel for everyday use but also the special steels demanded by the Nuclear Age . . . for example we produced the special steel plates for the reactor vessels at Calder Hall, Chapelcross and Bradwell and now we have been entrusted with the production of the plates for the nuclear power station reactor at Latina, Italy.



An interesting booklet "Steels for the Job", just published by us, describes some of our newer products. We shall be delighted to send you a copy.

Our Technical and Research Department will also welcome enquiries from any whose problem is . . . **STEEL**

CONSETT IRON COMPANY LIMITED, CONSETT, COUNTY DURHAM

Telephone: Consett 341 (12 lines) Telegrams: Steel Phone Consett

HOT ROLLED STEEL BARS

Round • Square • Flat

Ferro-Concrete Bars *bent to Specification*

HOT ROLLED STEEL HOOPS AND STRIP

Coils or cut lengths

COLD ROLLED STEEL STRIP

In all qualities including

Special Deep Stamping
in cut lengths or coils
Electro-Galvanised Strip

Speciality:

VERY HEAVY CONTINUOUS LENGTH COILS

THE WHITEHEAD IRON & STEEL CO LTD

Phone: 65401 (P.B.X.) **NEWPORT MON** *Grams: Whitehead Newport*

LONDON OFFICE
STEEL HOUSE,
TOTHILL STREET, S.W.1
Telegrams:
WHITEDSTEL, PARL, LONDON
Telephone:
WHITEHALL 2904

BIRMINGHAM OFFICE
KING EDWARD HOUSE,
NEW STREET, BIRMINGHAM, 2
Telegrams:
WHITEDSTEL, BIRMINGHAM
Telephone:
MIDLAND 0412-3

GLASGOW OFFICE
50 WELLINGTON STREET,
GLASGOW, C.2
Telegrams:
WHITEDSTEL, GLASGOW
Telephone:
CENTRAL 1528

MANCHESTER OFFICE
CHRONICLE BUILDINGS,
MANCHESTER
Telegrams:
WHITEDSTEL, MANCHESTER
Telephone:
BLACKFRIARS 1603-4

STEEL ROLLS

Forged and cast steel Work Rolls, Composite Back-up Rolls, and cast steel Back-up Rolls in carbon or alloy steels to suit the particular applications and service conditions

FOR BLOOMING MILLS
COGGING MILLS
PLATE MILLS

ESC

ENGLISH STEEL FORGE AND ENGINEERING CORPORATION LTD
ENGLISH STEEL CASTINGS CORPORATION LTD

wholly owned subsidiaries of English Steel Corporation Ltd., Sheffield

River Don Works, Sheffield

BROWN BAYLEY STEELS LIMITED SHEFFIELD

BROWN BAYLEYS

ADVERTISEMENT

Resistance Heating-1

In this form of heating, the heat is produced by passing an electric current through a high resistance conductor which is termed the " heating element ".

The heat is transferred from the heating element to the work by convection, radiation or conduction, or by a combination of any, or all of these. When it is a question of radiation or convection, the element can be a bare wire or strip of suitable material, provided it is adequately supported on electrical insulation capable of withstanding the temperature.

When there is to be contact between the work and the element, heat being transferred to the work by conduction, the wire or strip must be surrounded by suitable insulating material and enclosed in a protective sheath.

In the majority of cases, the wire or strip forming the heating element is made of a nickel-chromium alloy which has a high electrical resistance and can be safely used in air at temperatures of up to 1050°C., or in a suitable atmosphere, of up to 1150°C. Other element materials are available for use at higher temperatures.

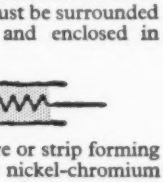
Sheathed elements, essential for contact heating but also used widely for convection and radiation heating because of the convenience afforded by the mechanical strength of the sheath, usually metallic, and by their "built-in" electrical insulation, cannot be used at temperatures as high as the bare wire or strip. This is because the wire, being embedded in insulation, is always at a higher temperature than the sheath, and to keep the wire temperature down to a safe figure the sheath temperature is usually limited to a maximum of around 800°C.

Automatic temperature control of resistance heating elements within narrow limits is easily effected, but if manual control only is desired, devices are available which enable the heat output of the elements to be controlled precisely at a required level. As with all electrical methods, a time switch may be included in the control circuit for automatically switching on or off at predetermined times, and this can enable, for example, an electric oven to be fully up to working temperature by the time the working day starts. Since there are no combustion products from the heaters, there is no need to build flues or special ventilating arrangements which also carry away useful heat.

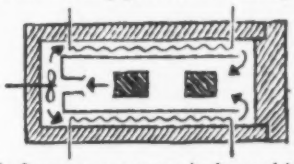
Electric resistance heating may profitably be put to many diverse uses; two of these are described briefly below, others will be listed in a subsequent data sheet.

Furnace Heating

Electric resistance furnaces can be divided into two main categories, batch type and continuous. In most cases, the heating elements are of nickel-chromium alloy, for furnace temperatures up to around 1050°C., but higher temperatures, up to nearly 3000°C., can be obtained by using other metals or alloys, or in some cases non-metallic elements. A protective atmosphere is desirable to prolong the life of some of these higher-temperature elements. For all temperatures, electric resistance furnaces can be constructed so that the heating process takes place in a controlled atmosphere if this is dictated by the composition or heat requirements of the work charge. In some furnaces, fans are used to circulate the air or special atmosphere over the charge, thereby giving increased heating rates and a uniform temperature over the whole charge.



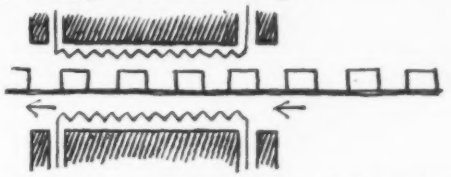
Automatic temperature control and program control of the heating process are readily effected.



Electric furnaces are extensively used in industry, for example in the general heat treatment of metals, in the glass and ceramics industries, for brazing and sintering, and for many other applications requiring temperatures above 500°C.

Oven Heating

There are two basic forms of heat transfer used in electric resistance ovens: convection and radiation. The latter is dealt with in a separate data sheet under the heading " Infra-Red Heating ".



Convection ovens may again be of the batch or continuous type. In either case, the charge is heated mainly by the movement of hot air, which is sometimes assisted, as in furnaces, by fans to give a rapid and uniform temperature rise. Ovens are normally designed for temperatures of up to about 500°C., and the heating elements are invariably of nickel-chromium or nickel-chromium-iron alloy.

Ventilation, when required, can be provided and regulated entirely to suit the heating process. Temperatures and times are readily controlled. A vacuum can be maintained in suitably designed ovens to assist in the extraction of moisture and solvent.

Convection ovens are extensively used for drying, baking and stoving operations, and for a host of other processes requiring a low or medium temperature.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, W.C.2.

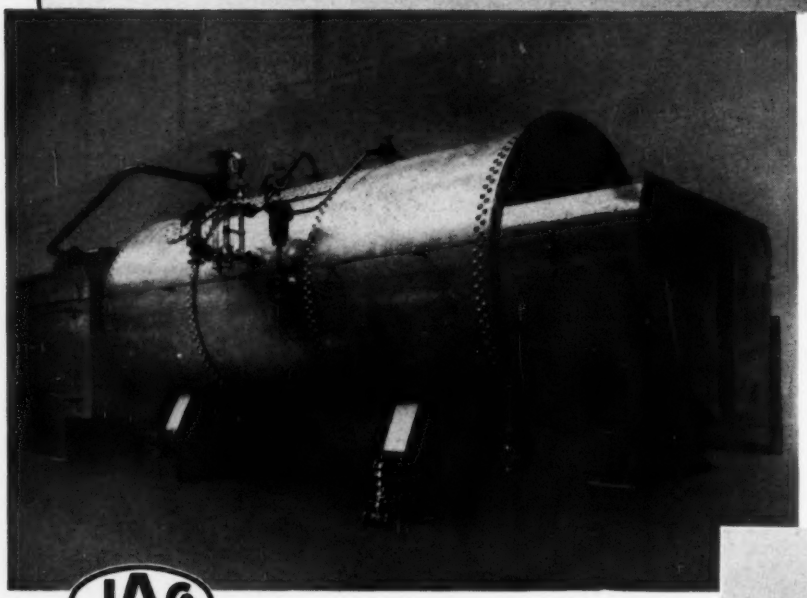
Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available—"Induction and Dielectric Heating" is an example; "Resistance Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

6780C

CUT HERE

JOSEPH ADAMSON
Waste Heat Boilers

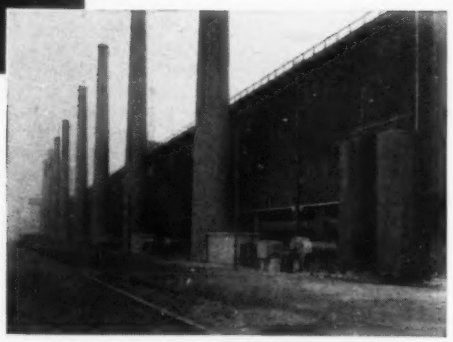


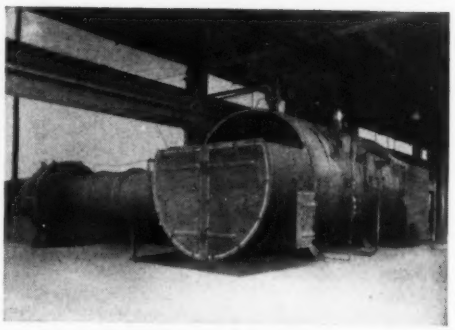
JAC

The Joseph Adamson Waste Heat Boiler is designed to make efficient use of the waste gases leaving open-hearth furnaces, reheating furnaces, soaking pits, gas retorts, etc.

The straight-through fire tubes have a high ratio of length to bore, giving about 90% tube efficiency and providing a large area of heating surface in a comparatively small space. Brickwork setting is not required and air infiltration is thus avoided.

A feature of Joseph Adamson Waste Heat Boilers is that a special cleaning device can be provided in the outlet chamber to allow the tubes to be cleaned while the boiler is at work.





JOSEPH ADAMSON & CO. LTD.
P. O. BOX 4 · HYDE CHESHIRE

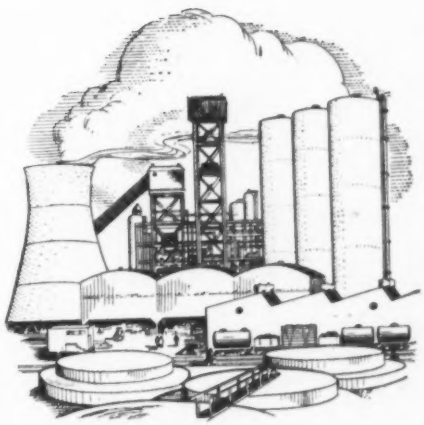
in association with
Adamson Alliance Co. Ltd., 165 Fenchurch St., London, E.C.3
Horsehay Company Ltd., Wellington, Shropshire

THE ADAMSON GROUP

75 motors in a large chemical plant

—all controlled from one central panel

This Dewhurst panel, recently installed in an extensive chemical plant situated on the North-East coast, provides positive central control of 75 motors, ranging from ½ to 50 h.p. located in various processing departments of the plant.



DUPAR

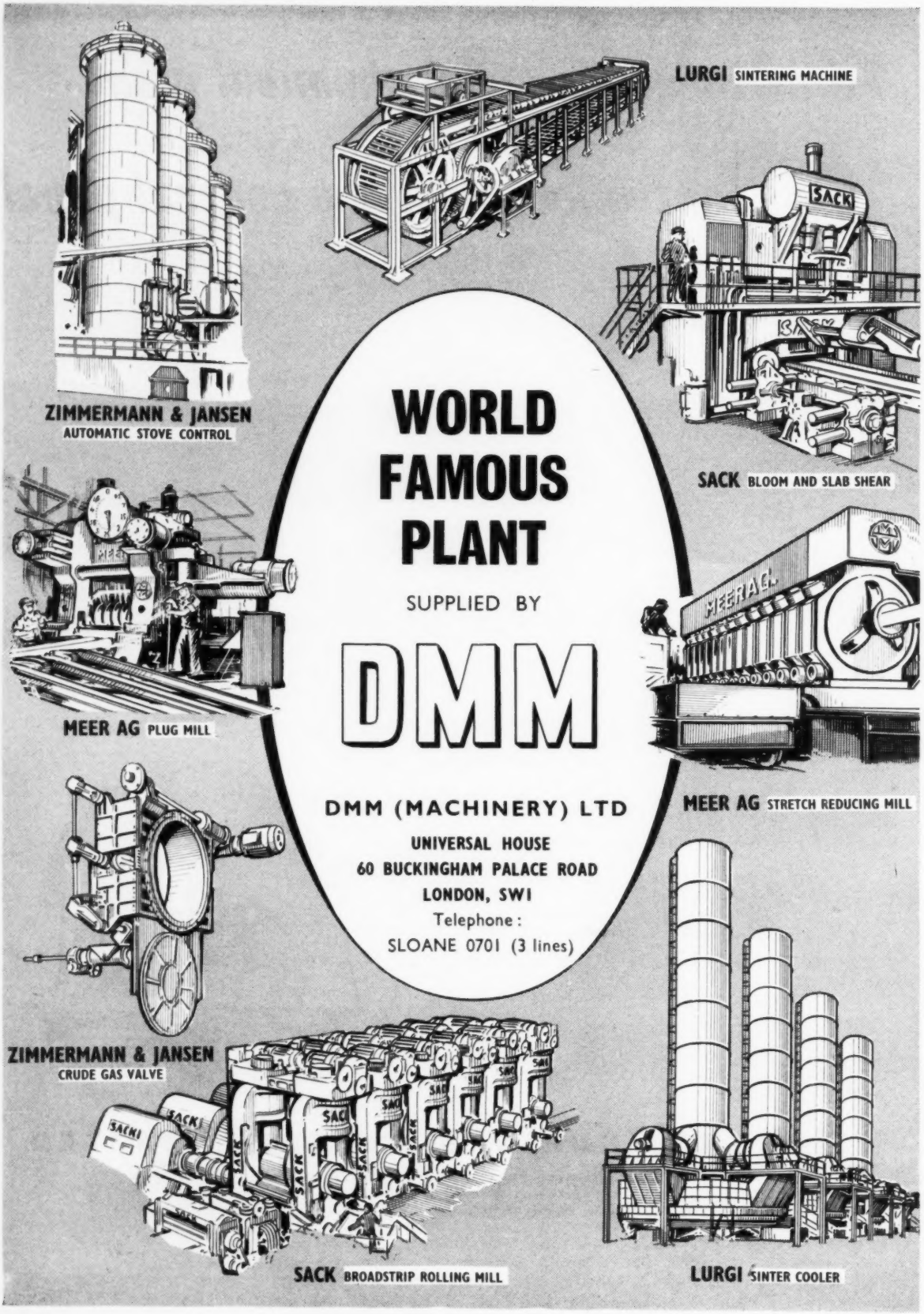
DEWHURST & PARTNER LIMITED

INVERNESS WORKS · HOUNSLOW · MIDDLESEX

Telephone: Hounslow 0083 (8 lines) *Telegrams: Dewhurst Hounslow*

and at BIRMINGHAM · GLASGOW · GLOUCESTER · LEEDS · MANCHESTER · NEWCASTLE · NOTTINGHAM

DP.15


ZIMMERMANN & JANSEN
AUTOMATIC STOVE CONTROL
LURGI SINTERING MACHINE
SACK BLOOM AND SLAB SHEAR
WORLD
FAMOUS
PLANT
SUPPLIED BY
DMM
DMM (MACHINERY) LTD
UNIVERSAL HOUSE
60 BUCKINGHAM PALACE ROAD
LONDON, SW1
Telephone:
SLOANE 0701 (3 lines)
MEER AG PLUG MILL
MEER AG STRETCH REDUCING MILL
ZIMMERMANN & JANSEN
CRUDE GAS VALVE
SACK BROADSTRIP ROLLING MILL
LURGI SINTER COOLER

RAWLBOLTS

for SPEED

STRENGTH

SECURITY

SAVE TIME with Rawlbolts. Grouted ragbolts will take 3 days to harden before the machine can be used. Use Rawlbolts and the machine can be in production in much less than 3 hours. It can be moved easily to a new position when necessary.

SAVE LABOUR with Rawlbolts. No laborious and time wasting cold chiselling with Rawlbolts. The holes are drilled with a Rawltool to the exact size, the Rawlbolts dropped in and after the machine has been positioned the bolts are tightened. The expansion of the segments locks the bolts in the holes.

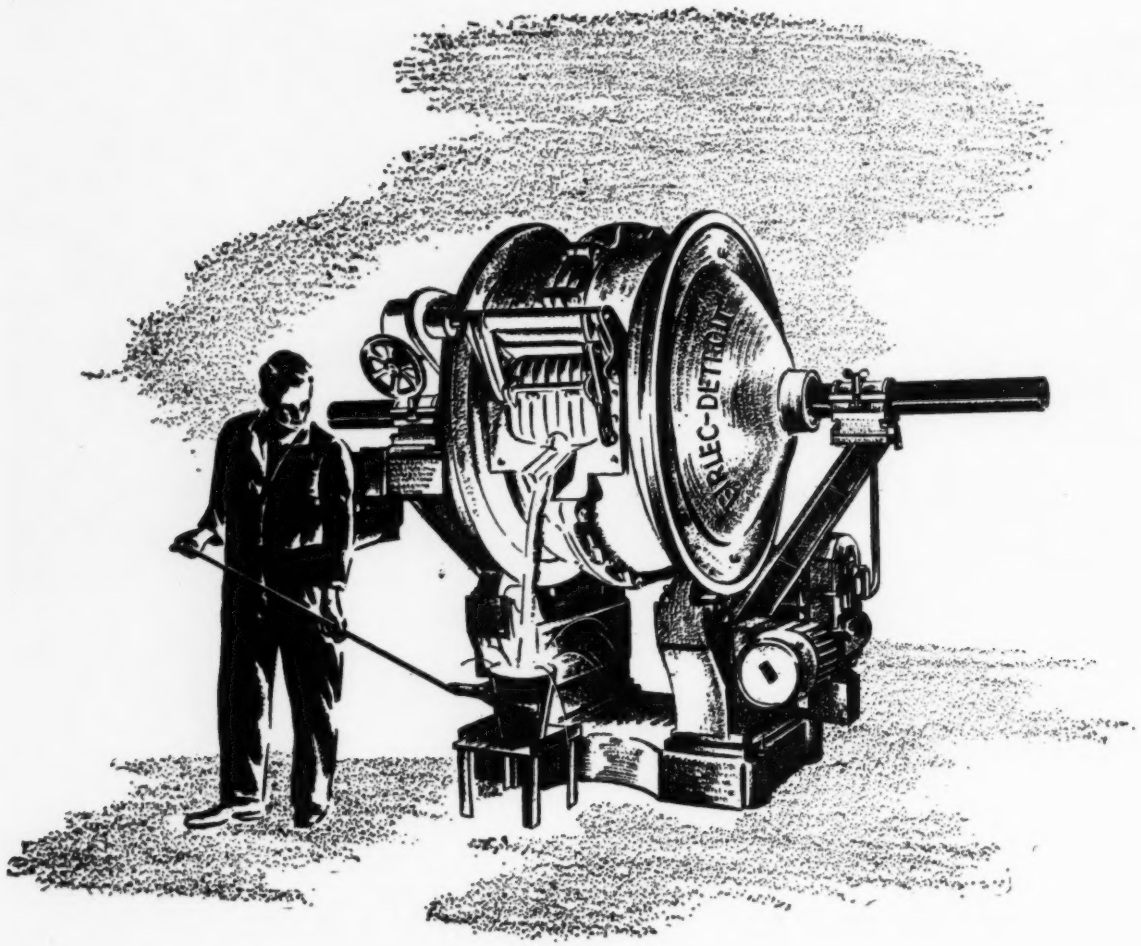
RAWLPLUG

The world's largest manufacturers of fixing devices

Write now *for descriptive broadsheet of R 1480 which incorporates a half size Rawlbolt Reference Chart.*

THE RAWLPLUG CO. LTD · CROMWELL ROAD · LONDON S.W.7

B549B



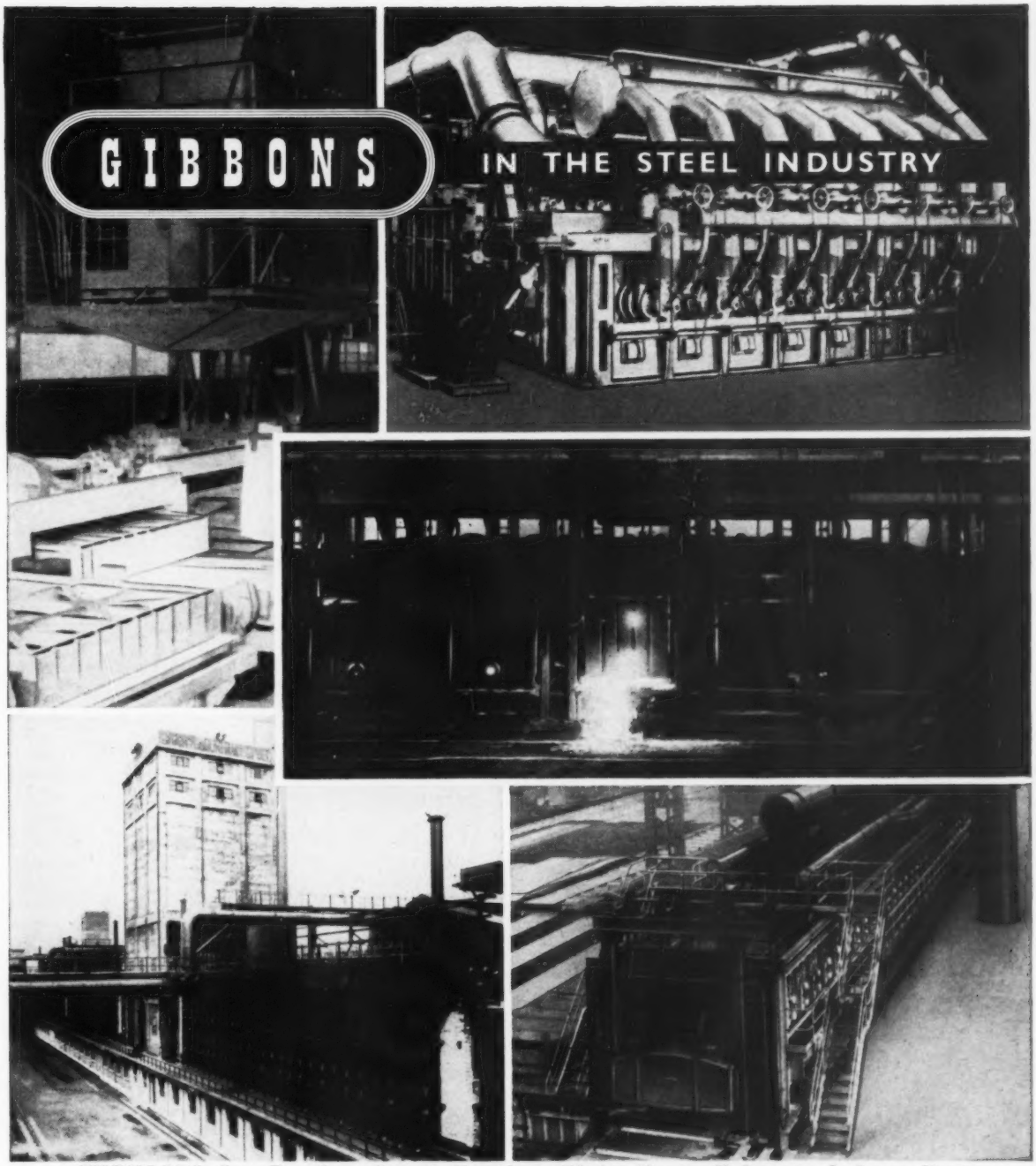
*ROCKING ARCS

The intense heat of an electric arc is put to excellent purpose in the versatile Rocking Arc Furnace which is so popular in modern foundries. To carry the arc and withstand the exceedingly high temperature demands an exceptional combination of strength, conductivity and refractory properties—in fact only an 'Acheson' graphite electrode is good enough. There is a size for every furnace.

ACHESON TRADE MARK **GRAPHITE**

The term Acheson is a Registered trade mark.

BRITISH ACHESON ELECTRODES LIMITED · WINCOBANK · SHEFFIELD · PHONE: ROTHERHAM 4836



FURNACES for Forging, Ingot Heating, Plate Normalising and Annealing

LICENSEES AND BUILDERS OF:

"OFU" SOAKING PITS AND CONTINUOUS SLAB REHEATING FURNACES

THERMO PATENT CONTINUOUS FURNACES

LOFTUS OPEN HEARTH FURNACES

WILPUTTE COKE OVENS

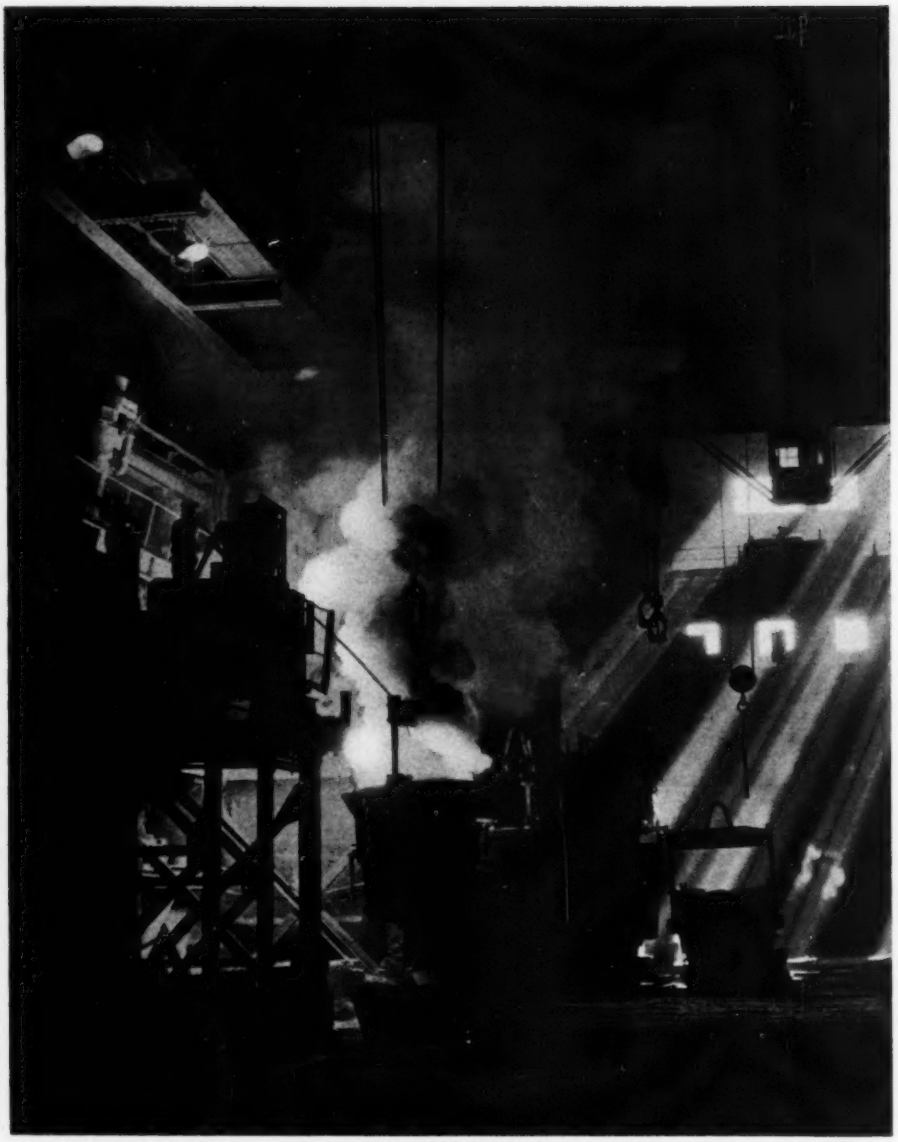
GIBBONS BROTHERS LIMITED P.O. BOX 19, DIBDALE, DUDLEY, WORCS.

Telephone: DUDLEY 3141 *Telegrams: "GIBBONS" DUDLEY*

LONDON OFFICE:— 151-156 PALACE CHAMBERS, WESTMINSTER, S.W.1.

NORTH EASTERN OFFICE:—"CRANBOURNE" 155 YARM ROAD, EAGLESCLIFFE, NR. STOCKTON-ON-TEES

Industry demands Steel —and Allen West Control Gear



Furnace tapping in the Electric Arc Melting Shop of Messrs Thos Firth & John Brown Ltd Sheffield, by whose courtesy this photograph is reproduced

Whatever the application, for every motor there is an Allen West starter

ALLEN WEST

- **Designed to B.S. Specification throughout**
- **Complete range—A.C. or D.C. automatic or hand-operated, from fractional to thousands of horsepower**
- **Single units or composite switchboards**
- **Crane Control Gear**
- **All classes of enclosure, from open-type to fully weatherproof**

ALLEN WEST & CO LTD BRIGHTON ENGLAND · Telephone: Brighton 23291 · Telegrams: Control, Brighton
Engineers and Manufacturers of Electric Motor Control Gear and Switchgear
SUBSIDIARY COMPANIES IN CANADA, SOUTH AFRICA AND RHODESIA AGENCIES THROUGHOUT THE WORLD

MAN AND MACHINE

Steel and many other metals have been worked for centuries but this modern age has discovered new metals and new uses for old metals and a demand for new machines to work the metals, new applications for the metals, metals in strips, tubes and wires, etc. For over 50 years, Robertson's have experimented, and built machines to deal with metals, machines built with performance and quality in mind and with high precision and high output in practice.

Robertson's machines, which are in operation throughout the world, help man to work metals ever faster, ever better and ever more accurately.

Photograph by courtesy of The Steel Company of Wales Ltd.

ROBERTSON
ROLLING MILLS

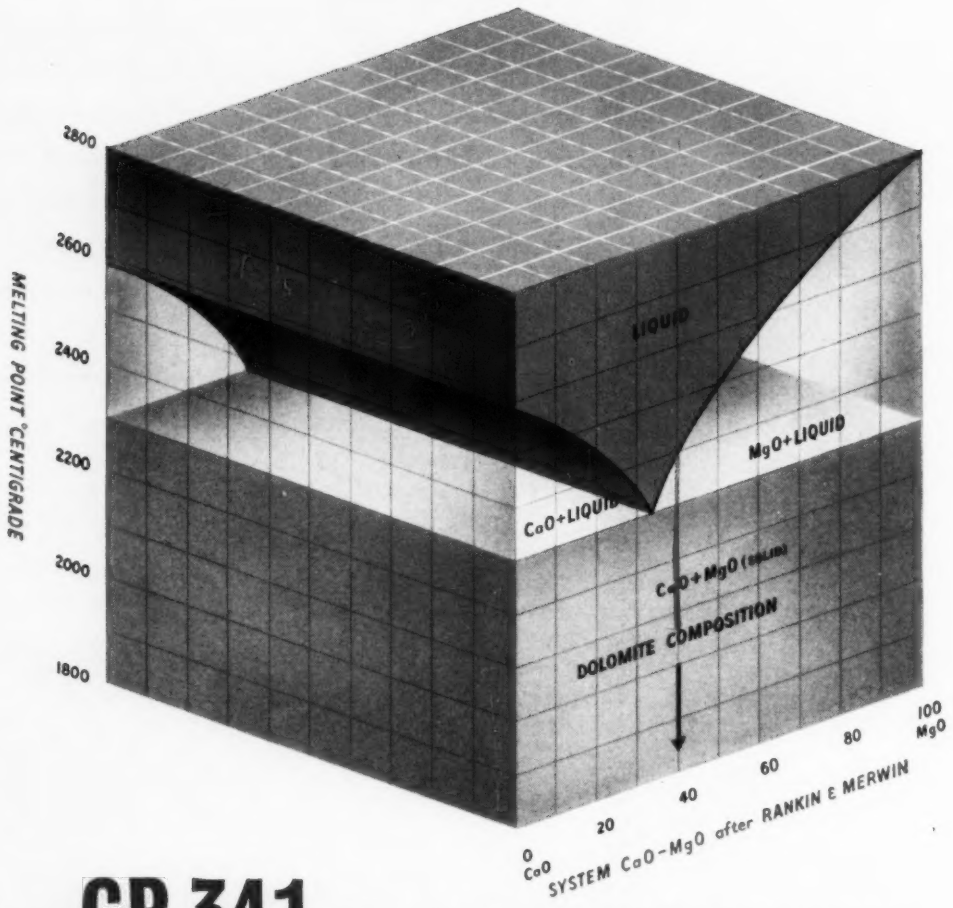
Robertsons manufacture a wide range of equipment for steel mills, and the illustration depicts a 32″ × 80″ two-high Sheet Skin Pass Mill installed in the Abbey Works of the Steel Company of Wales Limited.

W. H. A. ROBERTSON & CO. LTD., BEDFORD, ENGLAND

LICENSEES FOR THE BUILDING OF SENDZIMIR COLD REDUCTION MILLS & PLANETARY HOT MILLS, HALLDEN FLYING SHEAR MACHINES AND TORRINGTON WIRE FLATTENING AND EDGING MILLS. W.T. 305

Important News

for the Basic Steel Industry



New GR 341 Dolomite Brick Process

Dolomite an indigenous raw material relatively low in cost, is widely distributed in Great Britain. Its high melting point fits it for use in many metallurgical processes. Dolomite is the backbone of the basic steel industry. General Refractories have developed a new process of making bricks from this unique raw material, and they offer the "341" Dolomite brick to the steel industry for use in a wide range of applications.

APPLICATIONS

Basic Bessemer Converters

Basic O.H. Furnace sub-hearths, bottoms and checkers

Electric furnace side-walls and bottoms

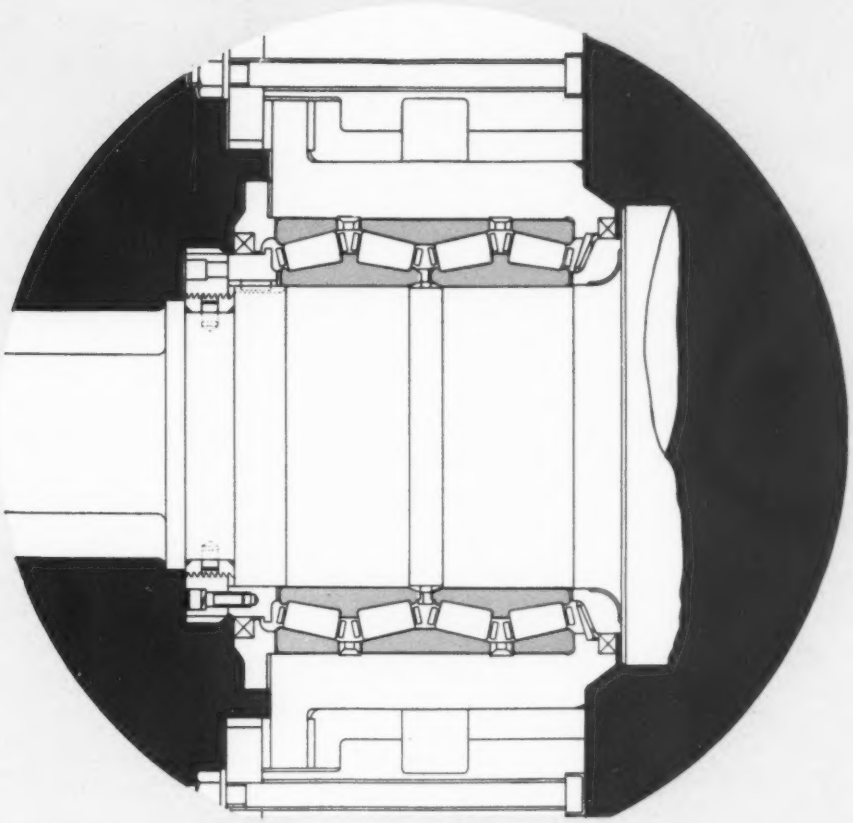
KAL-DO, L.D., ROTOR } *Oxygen-Steel Converters*

Active mixer sub-hearths and banks

GR Technical Service Department is available for consultation by users in the selection and application of these and other refractories.

GENERAL REFRACTORIES LTD.

GENEFAX HOUSE SHEFFIELD 10 TELEPHONE SHEFFIELD 31113



ON ALL ROLL-NECKS

of the new 45″ x 115″ Universal slabbing mill at

THE STEEL COMPANY OF WALES LTD

designed and built by DAVY-UNITED

TIMKEN REGD. TRADE MARK

TAPERED-ROLLER BEARINGS MADE IN ENGLAND BY

BRITISH TIMKEN

LIMITED

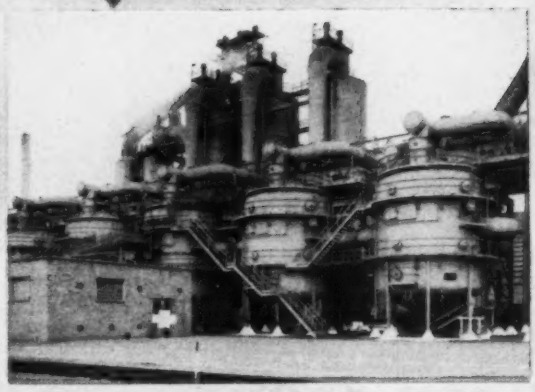
DUSTON, NORTHAMPTON (HEAD OFFICE) AND DAVENTRY, NORTHANTS

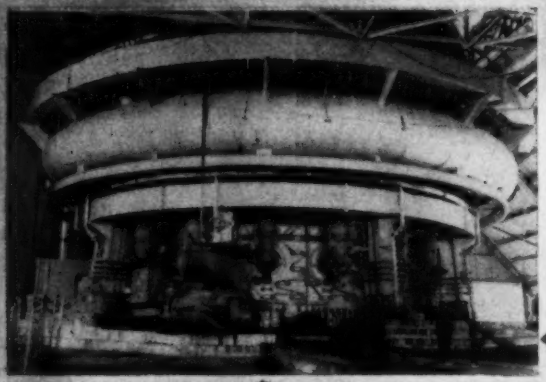
PLANT - by HEAD

Complete plant and

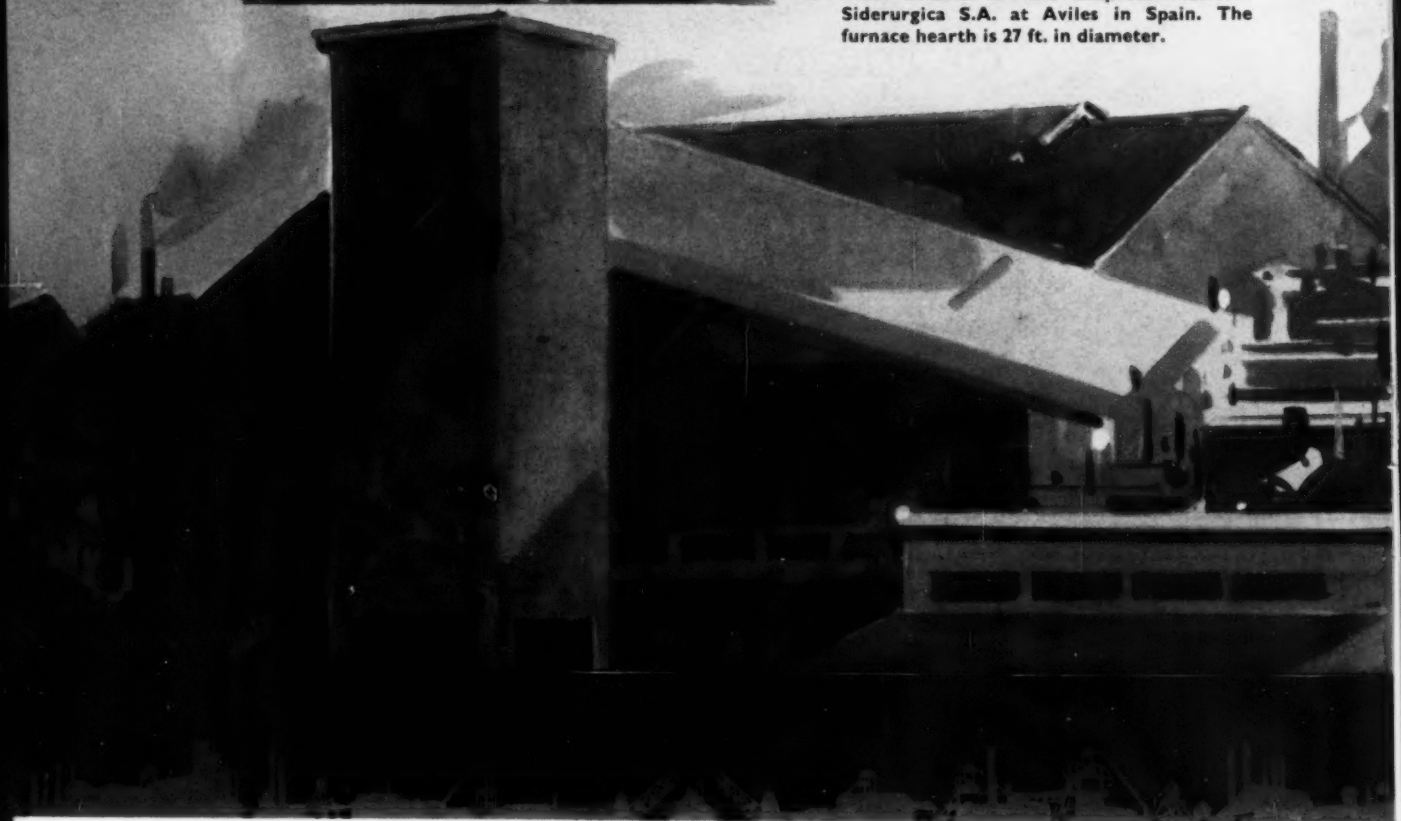
A 180 tons capacity Hot Metal Mixer Car manufactured by Head Wrightson Teesdale Ltd. to the design of the Treadwell Co. of America in conjunction with the International Construction Co

Gas cleaning plant for the Appleby – Frodingham. Steel Co.



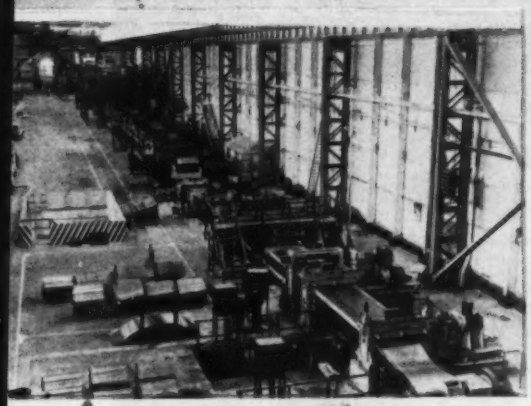


Blast furnace for the Empresa Nacional Siderurgica S.A. at Aviles in Spain. The furnace hearth is 27 ft. in diameter.



WRIGHTSON

services for the steel industry



The largest and most modern continuous galvanizing plant in Britain at the Ebbw Vale works of Richard Thomas & Baldwin Ltd.

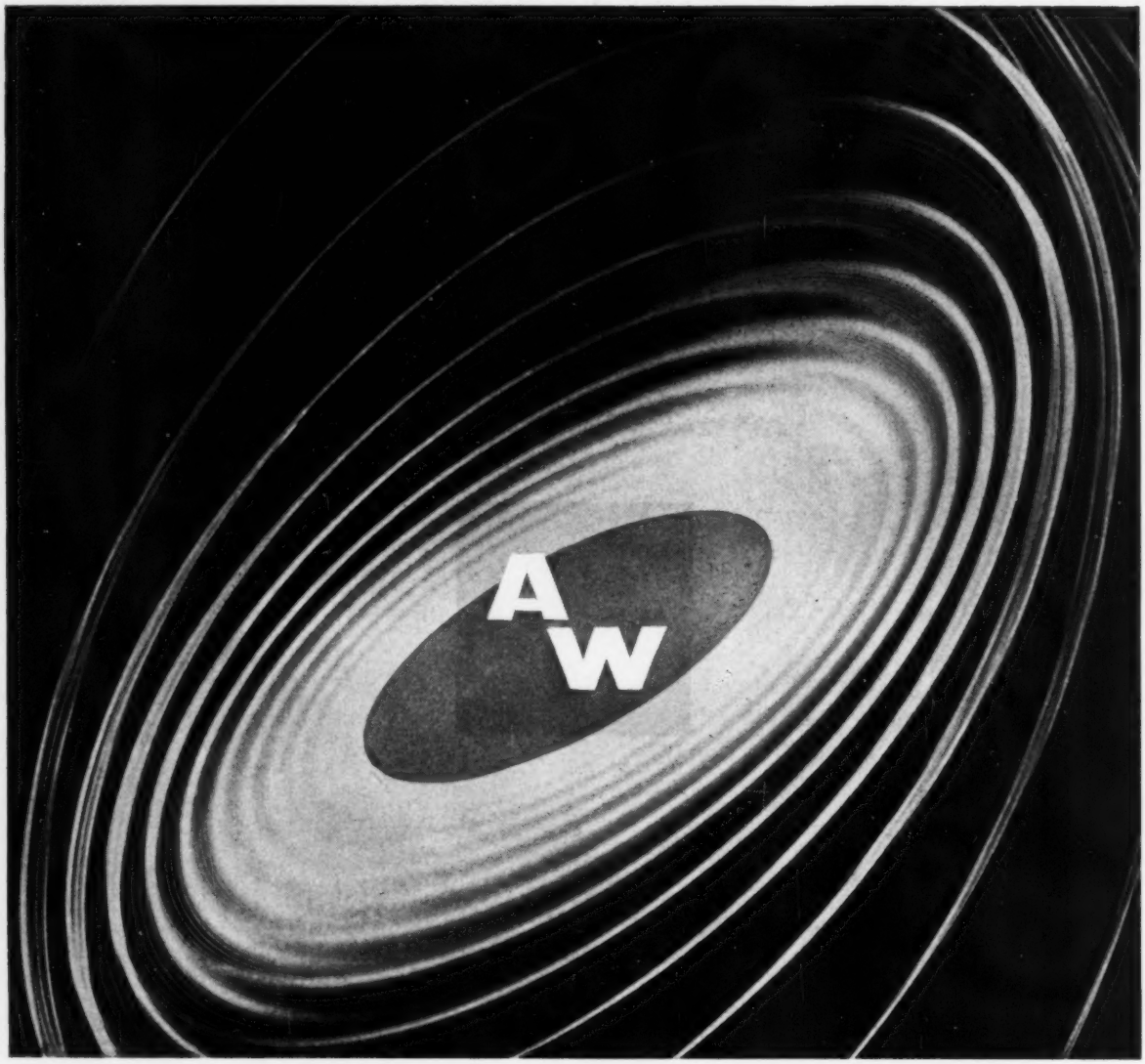
Electrolytic tinning line at the Velindre Works of the Steel Co. of Wales.

HEAD WRIGHTSON IRON & STEEL WORKS ENGINEERING LTD.

TEESDALE IRON WORKS, THORNABY-ON-TEES

THE HEAD WRIGHTSON MACHINE CO. LTD.

COMMERCIAL STREET, MIDDLESBROUGH



Scrutiny of youth

It is certainly the prerogative—and almost the duty—of each generation to question the ideas and loyalties of its predecessors. Were it not so progress would be slow indeed.

But to question does not always mean to reject. In industry, for instance, there are many examples of 'conservative' loyalties withstanding the fresh and searching scrutiny of youth.

There are enduring names in British industry, long-established companies whose own successive generations have contributed much to progress—without impairing that aura of un-noisy efficiency and complete dependability commanding a degree of confidence yesterday that is endorsed today and will be endorsed tomorrow.

We are very proud that year after year we continue to be numbered among them.

ARMSTRONG WHITWORTH (Metal Industries) LIMITED

Refined Iron · Iron Castings · Steel Castings · Clanlay Rolls · Kue-Ken Crushers · Beier I.V. Gears · General Engineering

CLOSE WORKS · GATESHEAD UPON TYNE 8

Subsidiary Company, JARROW METAL INDUSTRIES LTD., Western Road, Jarrow, Co. Durham

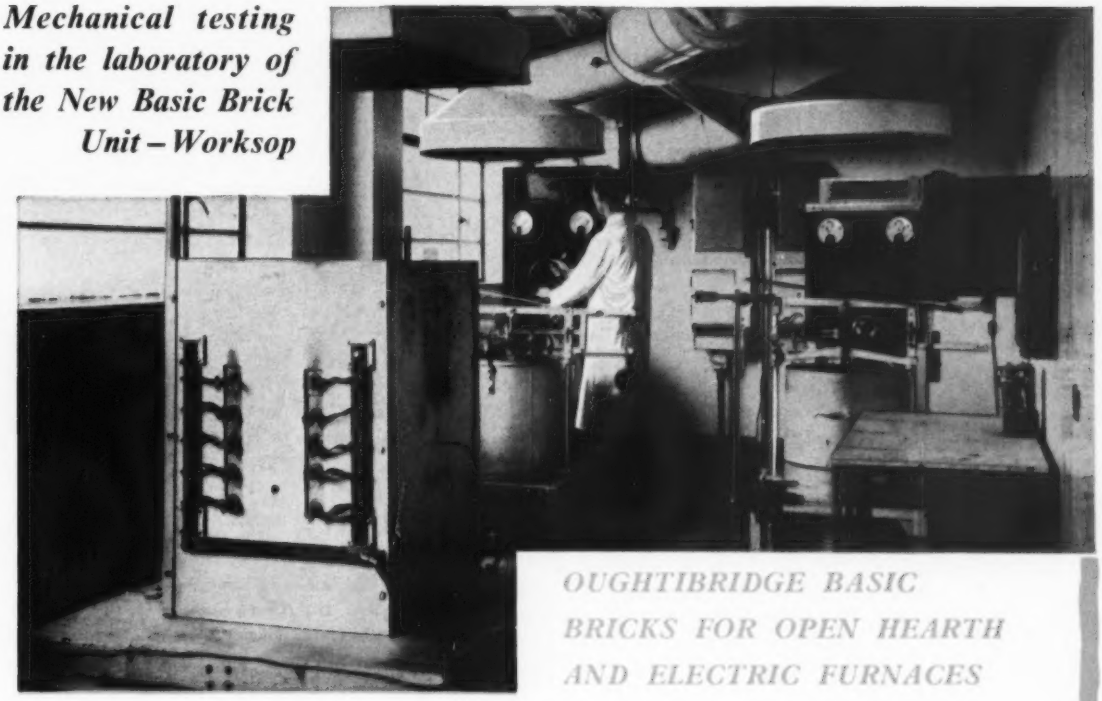
OUGHTIBRIDGE

LONG LIFE . . . HIGH MECHANICAL STRENGTH *AND LESS IN COST*

SERPEX 'A' BASIC BRICKS

Users of Serpex 'A' Basic Bricks have found that these bricks have a life equal to chrome-magnesite bricks, very high mechanical strength and offer strong resistance to flame abrasion . . . essential factors in economical furnace operation.

Mechanical testing in the laboratory of the New Basic Brick Unit – Worksop



OUGHTIBRIDGE BASIC BRICKS FOR OPEN HEARTH AND ELECTRIC FURNACES

UNFIRED CHROME-MAG BRICKS
SILICA BRICKS · MAGNESITE BRICKS
FIRED CHROME MAG BRICKS
METALKASE MAGNESITE BRICKS
SILCRETE BRICKS

In addition to the basic refractories mentioned, there is a wide range of Basic Cements, details of which we shall be glad to supply on request.

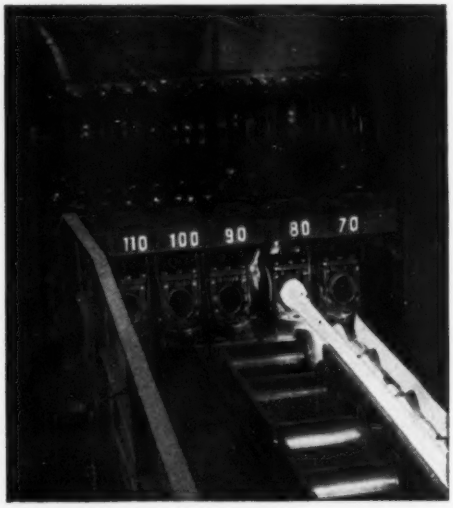
The OUGHTIBRIDGE SILICA FIREBRICK COMPANY LTD

A MEMBER OF THE STEETLEY ORGANIZATION

OUGHTIBRIDGE nr SHEFFIELD

TELEPHONE: OUGHTIBRIDGE 40804 · TELEGRAMS: SILICA PHONE, OUGHTIBRIDGE

8 good reasons why you should use these ROLLER GUIDES in your bar or wire rod mill



Nos. 125 and 155 roller guides fitted in a 27 1/2 in. (700 mm.) diameter, three-high stand for rolling 2 3/4, 3 3/16, 3 9/16, 4, 4 3/8 and 4 7/8 in. (70, 80, 90, 100, 110 and 124 mm.).

1 The entry friction guides are rigidly clamped into the guide box. They are intended to lead the oval to the groove in the roller, to protect the rollers against overloading, and to straighten bent rods.
The groove in the entry guides is made about 1/8" wider than the oval.

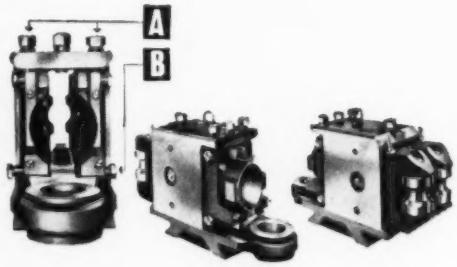
2 The rollers are mounted on leaf springs, which can be adjusted by means of the screws "B", and hold the oval steadily even if there should be some slight variation in the thickness of the oval.

3 If the thickness of the oval should vary, the springs of both rollers yield an equal amount, so that the oval remains in the centre of the groove.

4 To tilt the oval, the screws "A" are adjusted. One roller will then be lifted as much as the other is lowered.

5 As the oval is held very rigidly, the leader oval for wire rod may be thick, unless other circumstances call for a thinner oval.

6 The roller guide assemblies are narrow, and all screws that require adjustment during rolling are accessible from the front of the mill. No lateral space outside the guide box is therefore required for gaining access to the set screws, and the guide box assembly can thus be located close to the mill housing.



7 As the groove in the entry guides is wide and nothing but rolling friction acts on the oval, the latter is very easily introduced into the pass, and there is practically no risk of scratching the bar.

8 The roller guide may be used not only for leader and drawing oval passes but also for edging flats as well as for rolling squares, hexagons, octagons and various other sections, for instance in reduction passes for hexagon. It is suitable for all types of rolling mill. An important advantage is that the roller guide enables repeaters to be used in rolling plump leader-ovals.

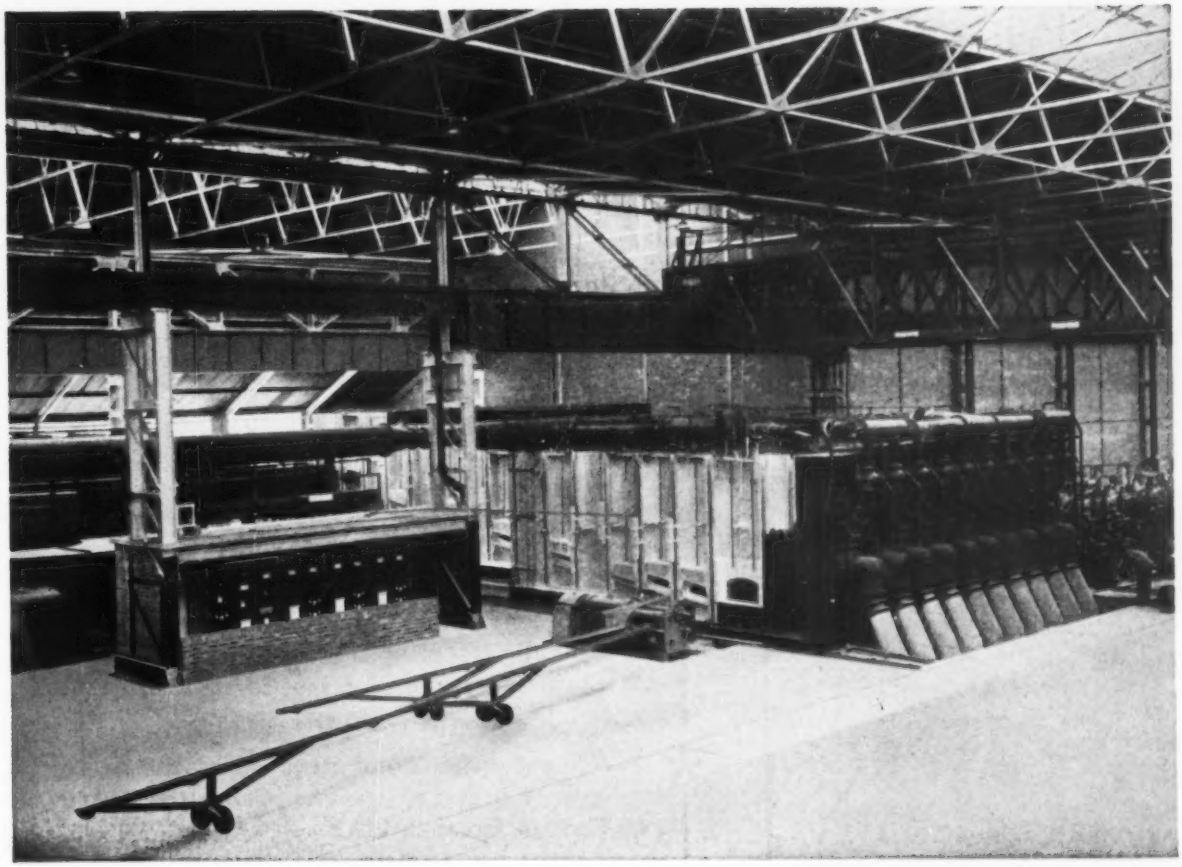
PS *Practically speaking, every bar and wire rod mill in Scandinavia uses roller guides of our design.*

MORGÅRDSHAMMAR

MORGÅRDSHAMMARS MEK VERKSTADS AB • MORGÅRDSHAMMAR • SWEDEN

Telegrams: Morgårdshammar, Ludvika, Sweden

For the complete story — send for your copy of Bulletin L3-1E.



BILLET REHEATING FURNACE WITH TYPHOON BURNER

HEATING FURNACES

OF ALL TYPES

ANNEALING FURNACES

REHEATING FURNACES

FORGE FURNACES

WIRE AND STRIP FURNACES

OTHER SPECIALITIES:

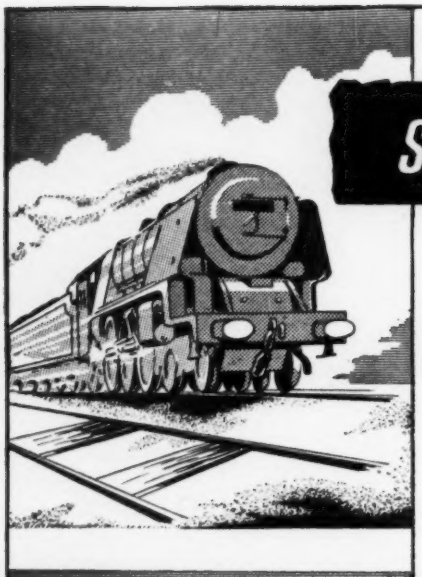
MORGAN GAS MACHINES ● SOAKING PITS (ISLEY CONTROLLED) ● HOT METAL MIXER CARS ● TYPHOON ROTARY FLAME GAS BURNERS ● MILL FURNACES ● MORGAN AIRJECTORS NASSHEUER CONTINUOUS BRIGHT ANNEALING FURNACES (SOLE LICENSEES)

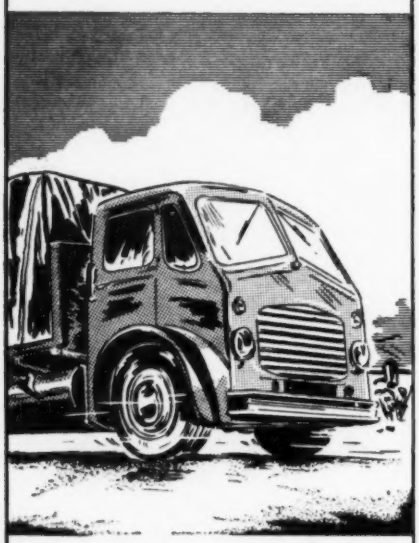
CONSULTATIONS AND REPORTS

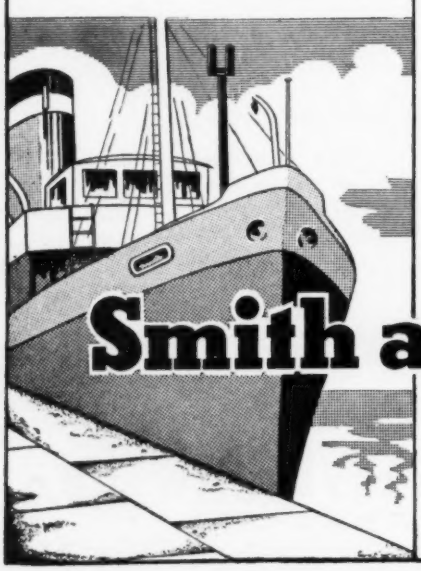
THE INTERNATIONAL CONSTRUCTION CO. LTD.

56 KINGSWAY · LONDON · W.C.2

Phone: HOLBORN 1871-2 Grams: SAHLIN, WESTCENT, 2 LONDON







Serving Britains Industry

GRIFFIN BRAND

STEEL SHEETS

* Light and Heavy industry are served by GRIFFIN BRAND Steel Sheets — Black, Galvanised, Flat and Corrugated.

* We make the widest Steel Sheets and have the largest general Galvanizing Plant in Great Britain.

* Metal Spraying by the most up-to-date methods done in our works or "in situ".

Metals deposited include: Zinc, Tin, Aluminium, Copper, and all its alloys, Cadmium, Monel Metal, etc.

Smith and McLean Ltd.

179 WEST GEORGE STREET,
GLASGOW, C.2

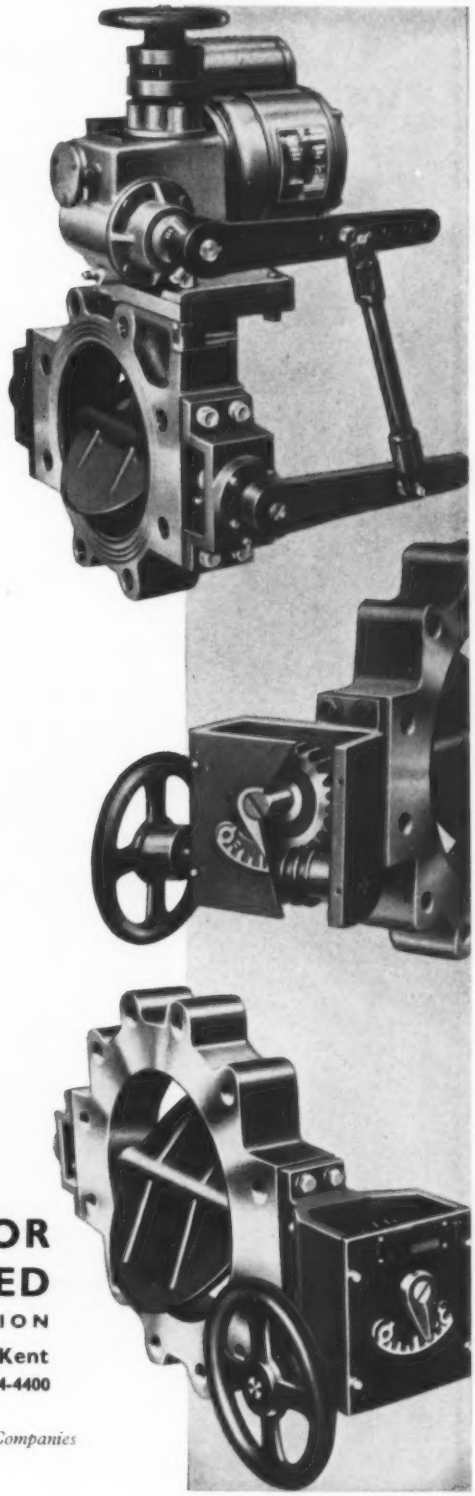
Tel.: CENtral 0442 'Grams: CIVILITY, Glasgow

FISHER

introduces . . . .

"CONTINENTAL"
BUTTERFLY VALVES

for GASES, VAPOURS, LIQUIDS, SEMI-LIQUIDS

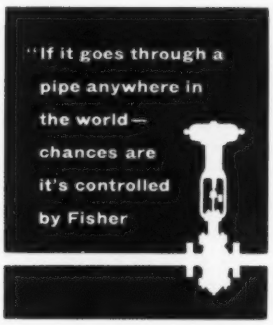


This extensive range of precision built butterfly valves provides the simplest and most economical answer to your valve problems—even to those beyond the scope of conventional units. Continental valves are more robust than the double flange type yet are compact—no thicker than a pair of pipe flanges—and easy to install.

For all methods of operation: manual; electric; diaphragm; piston.

For ANY size of pipe line at ANY pressure. Made in ANY metal or alloy, to operate at ANY temperature and ANY pressure.

THE MOST FLEXIBLE Valve System
for all Conditions of Operation.



Write for description leaflet

FISHER GOVERNOR COMPANY LIMITED
CONTINENTAL VALVE DIVISION
Airport Works · Rochester · Kent
Telephone: Chatham 4-4400

A Member of the Elliott-Automation Group of Companies

STEEL

PIG IRON AND CASTINGS

GUEST KEEN

IRON & STEEL COMPANY LIMITED,

EAST MOORS, **CARDIFF.**

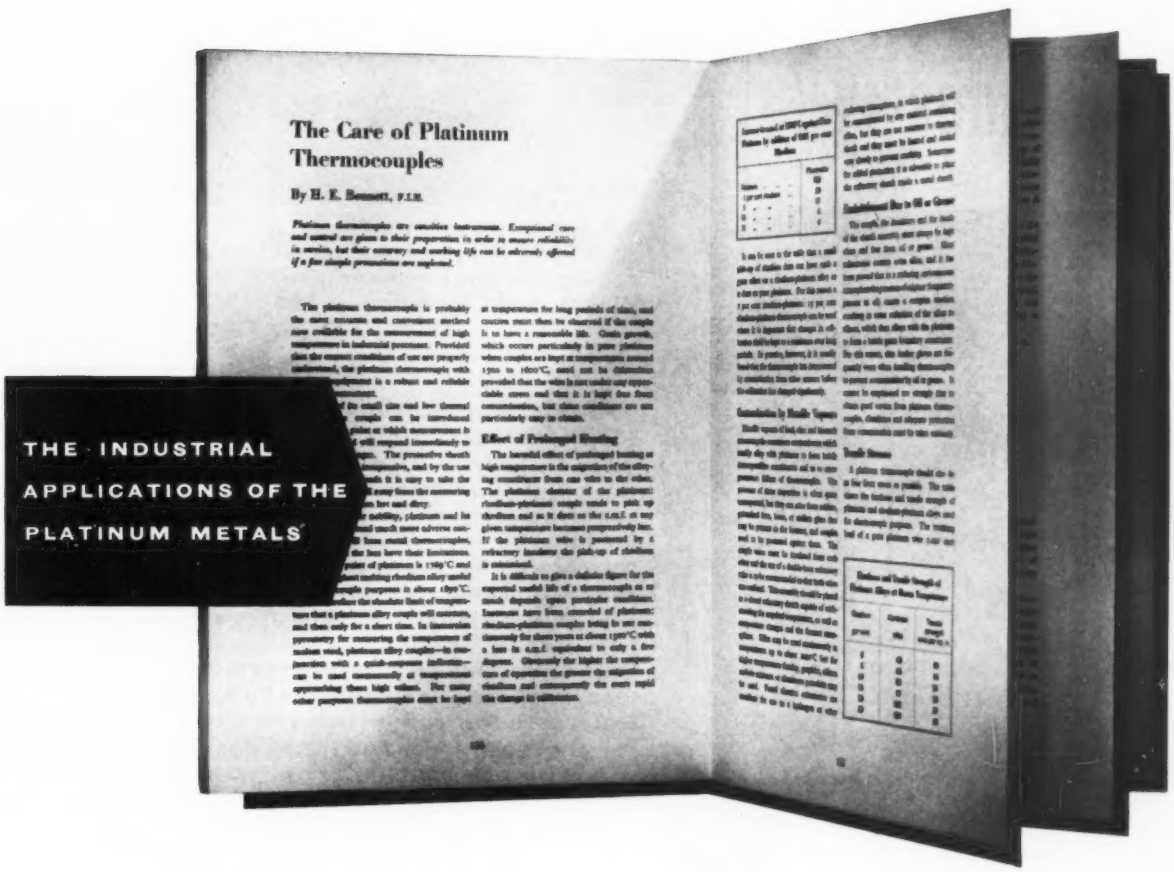
TELEPHONE: CARDIFF 33151

TRION

Platinum Metals Review

A quarterly survey . . .

In recent years the industrial consumption of the platinum metals has increased so rapidly that today nine-tenths of all platinum production is absorbed by industry. To provide research workers, engineers, chemists and metallurgists with up-to-date information, "Platinum Metals Review" is published quarterly. May we add your name to our mailing list?



Information regarding the properties of the platinum metals and their industrial applications is freely available.

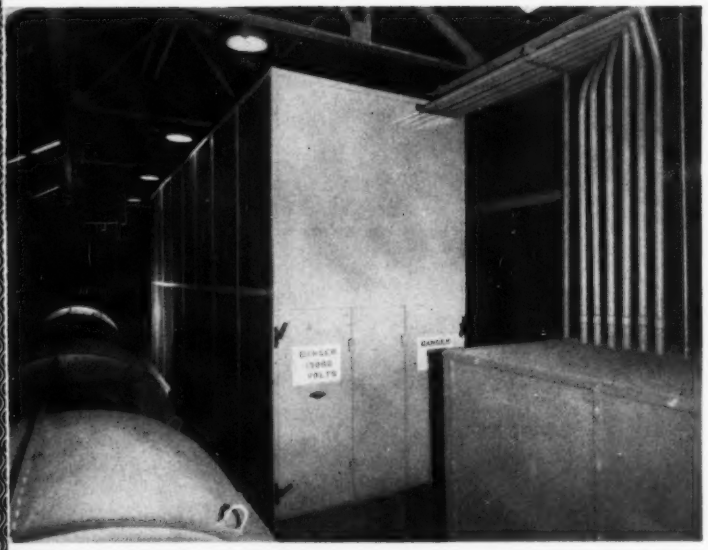
Johnson Matthey

JOHNSON, MATTHEY & CO., LIMITED, 73-83 HATTON GARDEN, LONDON, E.C.1 **Telephone: Holborn 6989**

Vittoria Street, Birmingham 1. Telephone: Central 8004 *75-79 Eyre Street, Sheffield 1. Telephone: 29212*

TRION

Electronic Air Filters for the Iron & Steel Industry



A Trion Electronic Air Filter installation cleaning the cooling air supplied to electrical equipment in a strip mill at the Hawarden Bridge Steelworks of Messrs. John Summers & Sons Ltd. The lower illustration shows the inlet face of the filter.

The extremely high efficiency of the Trion Electronic Air Filter, 90% Photometric Basis (99·5% on a weight basis), makes it eminently suitable for a wide variety of applications in the Iron and Steel Industry. It ensures that electric motors, switchgear and sensitive instruments are given adequate protection against the troublesome mass of small particles which can be the major cause of expensive breakdowns.

This extremely high efficiency does not mean that the Trion Electronic Air Filter is more expensive than other types of filter having much lower efficiencies. The initial cost is attractive, maintenance costs are negligible, expensive replacements unnecessary and power consumption exceptionally low.

TRION UK

For full details please write for publication No. 67/24

Industrial Applications:

W. C. HOLMES & CO. LTD.

Gas Cleaning Division, TURNBRIDGE, HUDDERSFIELD

Telephones: Huddersfield 5280 · London: Victoria 9971 · Birmingham: Midland 6830

Commercial Applications: Harris Engineering Co. Ltd., York Works, Browning St., London, S.E.17

9845

THE IRON AND STEEL INSTITUTE

4 Grosvenor Gardens, London, S.W.1

Council and Officers

PRESIDENT

Charles R. WHEELER, C.B.E.

PRESIDENT ELECT

William BARR, O.B.E.

PAST-PRESIDENTS

The Rt. Hon. the Earl of DUDLEY, M.C.
Sir Andrew McCANCE, D.SC., F.R.S.
J. R. MENZIES-WILSON, O.B.E.
Richard MATHER, B.MET.
Capt. H. Leighton DAVIES, C.B.E.
James MITCHELL, C.B.E.
The Hon. R. G. LYTTELTON
Sir Charles BRUCE-GARDNER, BT.
Herbert Henry BURTON, C.B.E., D.MET.
Arnold H. INGEN-HOUSZ

HONORARY TREASURER

William BARR, O.B.E.

VICE-PRESIDENTS

William Frederick CARTWRIGHT
Sir Charles F. GOODEVE, O.B.E., D.SC., F.R.S.
Edward Thomas JUDGE, M.A.
Donald Arthur OLIVER, C.B.E., M.SC.
Sir Julian PODE
Neville H. ROLLASON
Frank Henry SANITER, B.ENG.
Charles SYKES, C.B.E., D.SC., PH.D., F.R.S.

HONORARY VICE-PRESIDENTS

John Harold ANDREW, D.SC.
William Beck BAXTER, C.B.E.
Léopold BOUVIER
Donald Fraser CAMPBELL, M.A.
Alfonso de CHURRUCA
Wilfred John DAWSON, C.B.E.
Sir John DUNCANSON
Eugene Louis DUPUY, D.SC.
Dr Ing. Robert DURRER
Ian Frederick Lettsom ELLIOT
Léon GREINER
Berndt Gustaf GRÖNBLOM
Sir John E. JAMES
Sir William LARKE, K.B.E., D.SC.
Gustavus Henry LATHAM, LL.D.
Cyril E. LLOYD
Sir Arthur MATTHEWS, O.B.E., M.A.
Dr Joseph OBEREGGER
François PEROT
Pierre van der REST
Gunnar SCHJELDERUP
Baron WALCKENAER
Evert WIJKANDER

MEMBERS OF COUNCIL

William Charles BELL
John Hugh CHESTERS, D.SC. (TECH.), PH.D.
Eric Winearls COLBECK, M.A.
Frank Bernard GEORGE, B.SC.
William Frederic GILBERTSON
Richard Alan HACKING, O.B.E., M.SC.
John Watson JENKIN, B.SC., PH.D.
George Henry JOHNSON
Thomas JOLLY
Leonard Bessemer PFEIL, O.B.E., D.SC., F.R.S.
Arthur George QUARRELL, D.SC., PH.D.
Richard Felix SUMMERS
B. Chetwynd TALBOT
Geoffrey Weston WELLS
Charles Harry Trelease WILLIAMS

HONORARY MEMBERS OF COUNCIL

R. W. EVANS, T.D., M.MET.
L. F. C. NORTHCOTT, D.SC., PH.D.

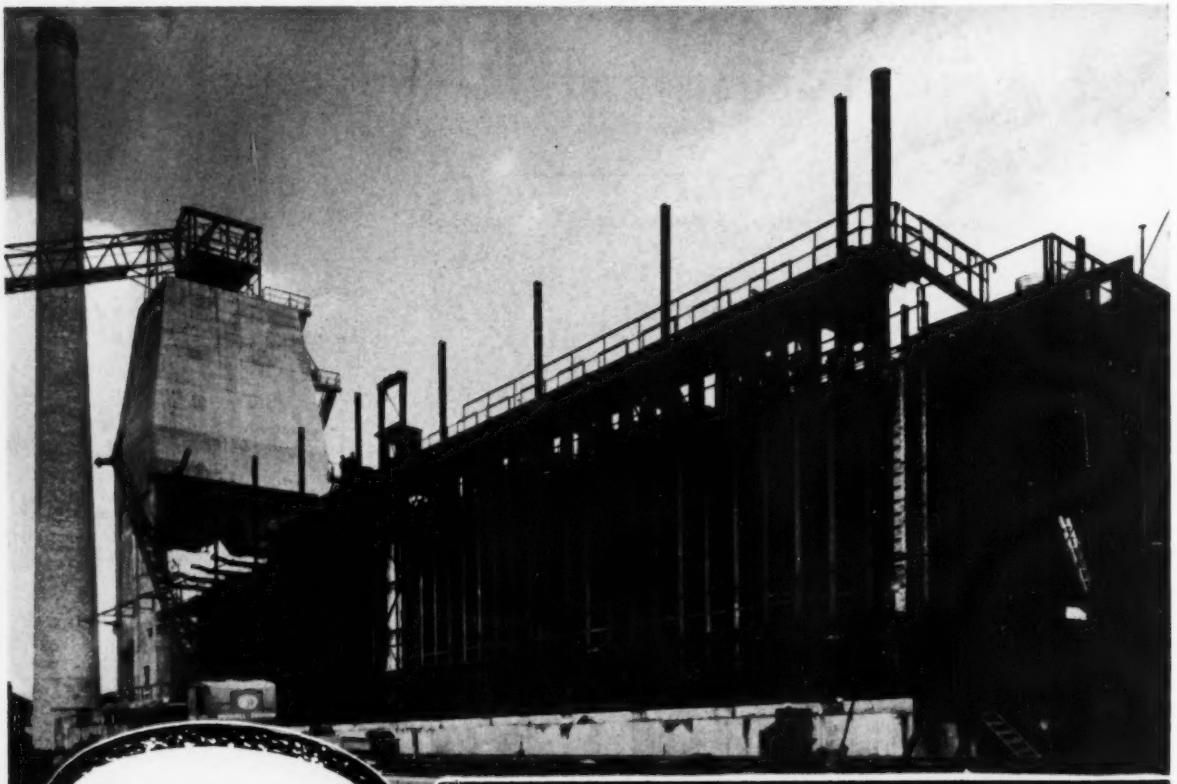
Commercial Director, British Iron and Steel Federation ... E. W. SENIOR, C.M.G.
Deputy Director, British Iron and Steel Research Association ... W. C. F. HESSENBERG, M.A.
President of The Institute of Metals ... Marshal of the Royal Air Force Lord TEDDER, G.C.B.
Chairman of the Engineering Committee ... F. B. GEORGE, B.SC.
President of the Cleveland Institution of Engineers ... T. H. STAYMAN
President of the East Midlands Metallurgical Society ... N. S. ANGUS, ASSOC. MET.
President of the Ebbw Vale Metallurgical Society ... P. EDWARDS
President of the Leeds Metallurgical Society ... K. HILL
President of the Lincolnshire Iron and Steel Institute ... A. H. NORRIS
President of the Liverpool Metallurgical Society ... C. BODSWORTH, M.MET., PH.D.
President of the Manchester Metallurgical Society ... J. Y. DAVIES
Chairman of the Newport and District Metallurgical Society ... H. H. STANLEY, ASSOC. MET.
Chairman of the North Wales Metallurgical Society ... H. BROOKE FREEMAN, D.I.C., A.R.S.M.
President of the Sheffield Metallurgical Association ... A. G. QUARRELL, D.SC., PH.D.
President of the Sheffield Society of Engineers and Metallurgists ... H. BULL, ASSOC. MET., F.I.M.
President of the Staffordshire Iron and Steel Institute ... W. H. B. WESSON, T.D.
President of the Swansea and District Metallurgical Society ... R. HIGGINS, O.B.E., PH.D., B.SC.
President of the West of Scotland Iron and Steel Institute ... H. HARRIS, PH.D., B.SC., D.I.C.
Representatives of The Institution of Metallurgists ... E. J. BRADBURY
W. E. BARDGETT

SECRETARY

K. HEADLAM-MORLEY

ASSISTANT SECRETARY

A. POST, T.D.



GLASSHOUGHTON
FIRST INSTALLATION
42 OVENS

NEW coking plants under construction

APPLEBY-FRODINGHAM
SECOND INSTALLATION
66 OVENS

CORBY-DEENE
FIRST INSTALLATION
51 OVENS

Operating Nov. 1958
MURTON
FIRST INSTALLATION
50 OVENS

Operating July 1958
PRETORIA
SIXTH INSTALLATION
51 OVENS

VANDERBIJL PARK
THIRD INSTALLATION
55 OVENS

BAIRDS
SECOND INSTALLATION
37 OVENS

LYSAGHT
FIFTH INSTALLATION
23 OVENS

PRETORIA
FIFTH INSTALLATION
51 OVENS

REDBOURN
THIRD INSTALLATION
62 OVENS

The New Batteries of W-D Becker Underjet Coke Ovens at the Glasshoughton Works of the North Eastern Division of the National Coal Board nearing completion.
The Batteries will carbonise some 880 tons of coal daily from which blast furnace, domestic and industrial coke and town gas will be produced.

WOODALL—DUCKHAM
Construction Company Ltd.

Woodall-Duckham House, 63-77 Brompton Road, London, S.W.3. Tel: KENsington 6355 (14 lines) Grams: Retortical (Southkens) London

Journal of The Iron and Steel Institute

APRIL, 1959
Vol. 191 Part 4

Published Monthly

©
The Iron and Steel Institute

EDITOR
K. Headlam-Morley

MANAGING EDITOR
E. R. Mort, B.SC., F.I.M.

PRODUCTION EDITOR
H. F. Cleere, B.A.

ASSISTANT EDITORS
J. M. Grant, M.A.
R. J. D. Harvey, B.A.

EDITORIAL AND ADVERTISEMENT OFFICES

4 Grosvenor Gardens, London, S.W.1
SLOane 0061
Telegrams - - Irosamente, Sowest

SUBSCRIPTIONS

Members Free - Extra Copies Prices on application
Non-members - £10.0.0 per annum
Single Copies £1 each
Packing and Postage 1s. per copy

NOTE

The Institute as a body is not responsible for statements made or opinions expressed in papers, articles, or discussions appearing in the Journal of The Iron and Steel Institute.

Contents

THE IRON AND STEEL INSTITUTE

The use of oxygen in duplex and stationary open-hearth practice *by O. Pearson* 305

Some investigations on the treatment of molten iron *by W. B. Chater and J. A. Charles* 319

The practical aspects of pretreatment processes *by J. L. Harrison* 328

The use of oxygen in a modified tilting furnace *by A. Jackson* 337

The removal of hydrogen by diffusion from large masses of steel *by J. D. Hobson* 342

The distortion of high-carbon high-chromium die steel *by K. Sachs and G. T. F. Jay* 353

The effect of austenitizing treatment on the formation of lower bainite in a plain carbon steel *by L. W. Graham and H. J. Axon* 361

IRON AND STEEL ENGINEERS GROUP

Equipment used for vacuum melting and casting in the iron and steel industry *by A. S. D. Barrett and M. E. Harper* 366

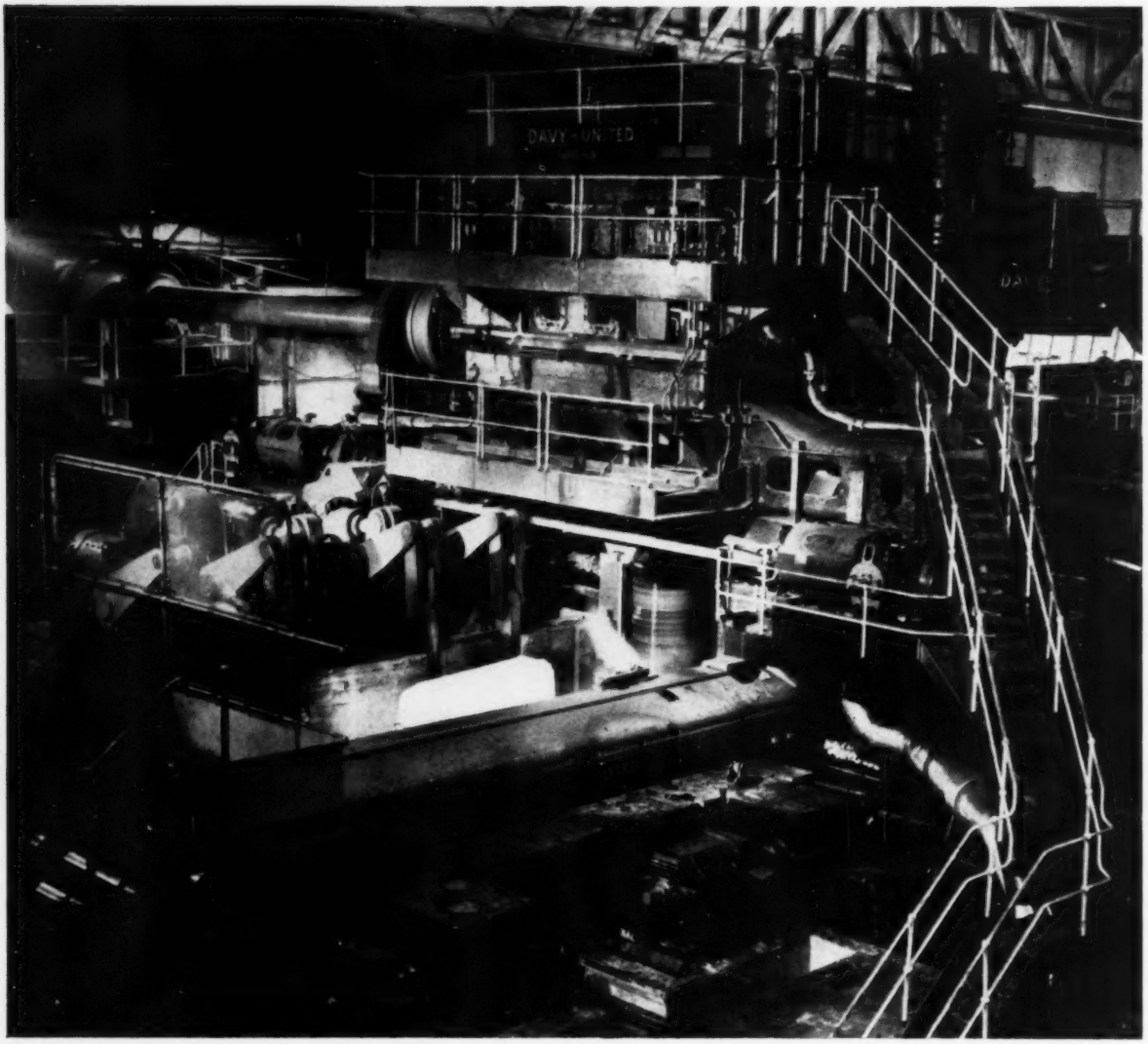
Report of the 37th Engineers Group Meeting 374

Discussions at the 37th Engineers Group Meeting 374

NEWS 390 **ABSTRACTS** 395

TRANSLATIONS 394

THE IRON AND STEEL INSTITUTE, 4 GROSVENOR GARDENS, LONDON, S.W.1



UNIVERSAL SLABBING MILL

at the STEEL COMPANY OF WALES

The new 45″ × 115″ Universal Slabbing Mill at the Abbey Works of The Steel Company of Wales can roll 20 ton ingots at the rate of 60,000 tons a week, 12,000 tons more than was possible on the mill replaced. Unique in design, this mill is the product of three years of combined planning between the engineers of Davy-United and The Steel Company of Wales.

DAVY-UNITED

Sheffield · Middlesbrough · Glasgow

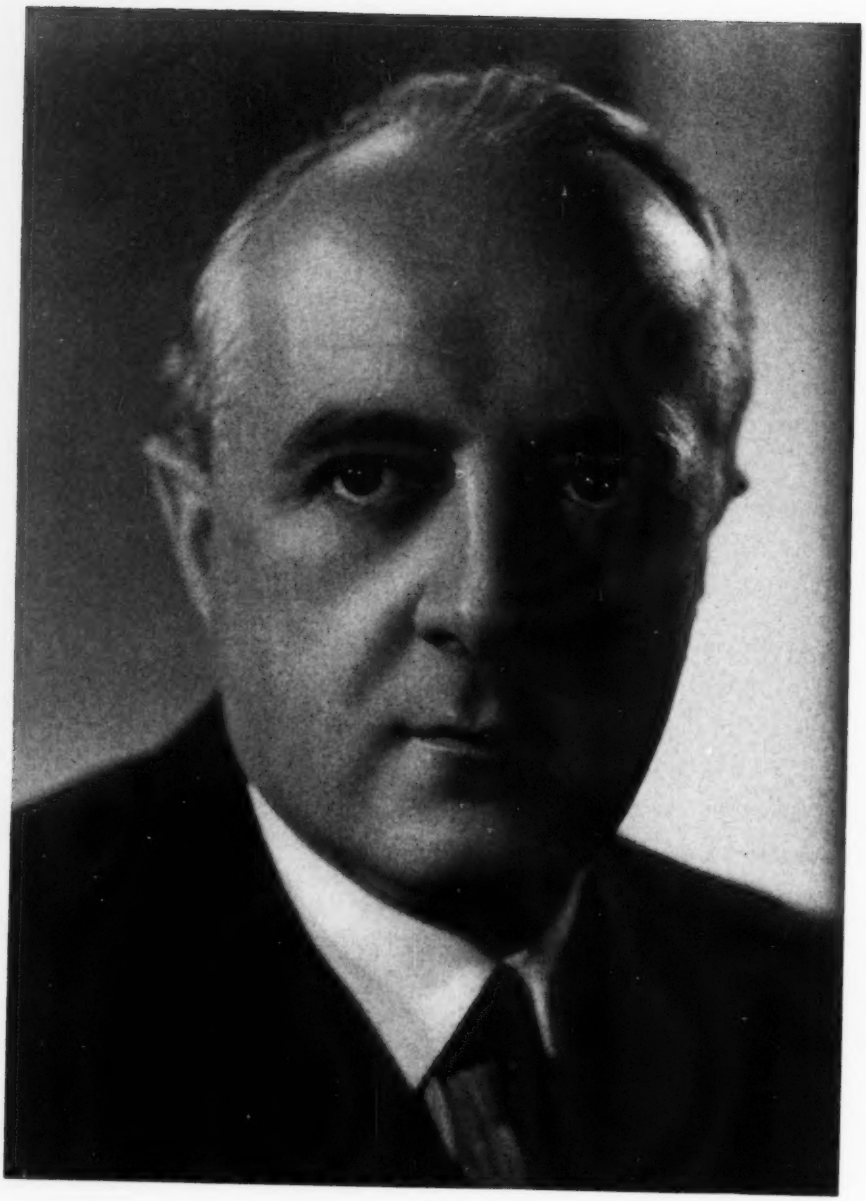
308/DU

R. F. SUMMERS

RICHARD FELIX SUMMERS, son of the late Henry Hall Summers and grandson of the late John Summers, founder of John Summers and Sons Ltd, was born in 1902 at Stalybridge, Cheshire. He was educated at Shrewsbury and at Clare College, Cambridge. In 1925 he married Evelyn, daughter of W. F. Irvine, F.S.A., of Corwen, Merioneth; they have four sons, two at present employed by John Summers and Sons Ltd and two at Cambridge.

In 1925 Mr Summers entered the family company; he became a director in 1931, managing director in 1936, and chairman in 1938. He is in addition a director of The United Steel Companies Ltd, the Steetley Company Ltd, the District Bank Ltd, the Royal Insurance Co. Ltd, and the London Liverpool and Globe Insurance Co. Ltd, a member of the Midland Area Board of the British Transport Commission, a member of the Institute of Transport, and a governor of Shrewsbury.

Mr Summers joined The Iron and Steel Institute in 1945, and was elected a Member of Council in May, 1958.

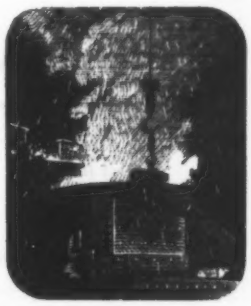


R. F. Summers

Member of Council

PAPERS AND REPORTS ON RESEARCH AND PRACTICE

Metallurgy · Plant Operation · Research



The use of oxygen in duplex and stationary open-hearth practice

By Oscar Pearson

SYNOPSIS

Oxygen usage in open-hearth furnaces has been increasing steadily. Its application for air enrichment and with submerged lance pipes for decarburization is well established. The present practice of using vertical roof lances before and immediately after hot metal additions has considerably increased furnace operating rates in stationary O H furnaces operating on high hot-metal charges. When used in conjunction with basic roofs furnace availability can remain at a high level. Trials of a similar practice using roof lances in tilting furnaces with silica roofs and high hot-metal charges has resulted in less output and lower furnace availability than obtained with conventional duplex practice employing blown metal charges from acid-lined converters. 1697

THIS PAPER describes recent developments in the use of oxygen in open-hearth practices in the United States Steel Corporation plants.

The Gary Steel Works, the largest single plant, with one duplex and four stationary O H shops containing a total of 53 furnaces, plays a very important role in total operations and is of major importance in expanding to meet increasing steel requirements.

Due to interest in expanding ingot producing facilities, the five units have been examined in order to determine the extent to which each might participate in the future growth of this plant.

The duplex operation at No. 2 O H and Bessemer shop plays a significant part in the expansion programme as it produces cold charge metallics for the other four shops and acts, therefore, as a stabilizer for the plant as a whole. The present practice in No. 2 Shop as well as the potential future programmes will be reviewed.

In studying the future course our efforts might follow, the following likely operating methods have been considered.

(1) Additional tonnage from current duplex operations through provision of additional hot metal capacity and auxiliary facilities.

(2) Elimination of the Bessemer converters and the production of equivalent O H tonnage in the three tilting furnaces by using oxygen roof lances to increase production rate. Basic hot metal at 0·85 hot metal to ingot ratio would be charged together with requisite charge ore.

(3) Replacement of tonnage from current duplex operations through vertical oxygen lance practice in new stationary furnaces with about double the capacity of present tilting furnaces. These would tap into two ladles and employ a hot metal charge of 0·50–0·60 hot metal to ingot ratio.

Present facilities, as well as the results to date of efforts to develop a suitable method of improving them, will now be described. As can be seen from the alternative methods proposed, oxygen will play an important part in either method used.

GARY STEEL WORKS

In order to orient properly the position of No. 2 Open Hearth Shop in its relationship to other producing facilities at the Gary, Indiana Steel Works of United States Steel Corporation, the general arrangement of the entire plant will be briefly described.

Included in the plant are 16 batteries of coke ovens, 12 blast furnaces, 53 O H furnaces, three Bessemer converters, 46-in. and 36-in. slabbing mills, 44-in. and 40-in. blooming mills, a 160-in. plate mill, a rail mill, a continuous billet mill, 12 merchant bar mills, a 38-in. hot strip mill, wheel mill, and axle mill. Figure 1 shows the relationship of these facilities as well as three associated plants which process some of the semi-finished products.

Manuscript received 23rd February, 1959.
The author is the Vice-President, Operations-Steel, United States Steel Corporation.

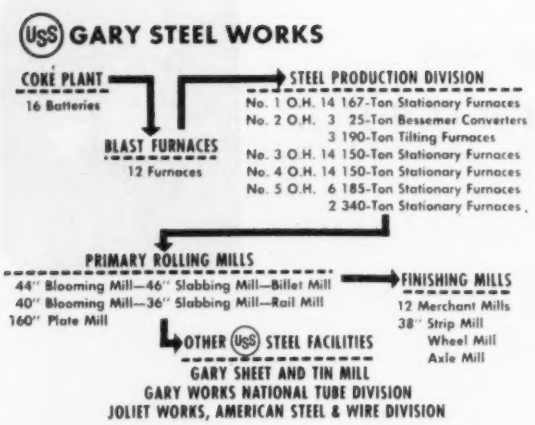

USS GARY STEEL WORKS
COKE PLANT
16 Batteries
BLAST FURNACES
12 Furnaces
STEEL PRODUCTION DIVISION
No. 1 O.H. 14 167-Ton Stationary Furnaces
No. 2 O.H. 3 25-Ton Bessemer Converters
3 190-Ton Tilting Furnaces
No. 3 O.H. 14 150-Ton Stationary Furnaces
No. 4 O.H. 14 150-Ton Stationary Furnaces
No. 5 O.H. 6 185-Ton Stationary Furnaces
2 340-Ton Stationary Furnaces
PRIMARY ROLLING MILLS
44" Blooming Mill—46" Slabbing Mill—Billet Mill
40" Blooming Mill—36" Slabbing Mill—Rail Mill
160" Plate Mill
FINISHING MILLS
12 Merchant Mills
38" Strip Mill
Wheel Mill
Axle Mill
OTHER USS STEEL FACILITIES
GARY SHEET AND TIN MILL
GARY WORKS NATIONAL TUBE DIVISION
JOLIET WORKS, AMERICAN STEEL & WIRE DIVISION

Fig. 1—Diagrammatic representation of the relationship of the facilities at the Gary Works

The planned passage of material from the coke works to the blast furnaces, and subsequently to open hearths, strippers, primary and finishing mills is readily apparent, if seen from the air. Transportation and material movement are major problems in a plant of this size and considerable planning and coordination are required. Although designed some fifty years ago the symmetry of arrangement with proper recognition of straight line material flow is easily recognizable. It is a major tribute to the early designers that our newest integrated plant, constructed since 1950, uses the general design of Gary Works as a model. To define further the magnitude of material requirements there is listed in the following table the availability of products from three major plant divisions.

*Availability of products per year, net tons**		
Coke	*Hot metal*	*Ingots*
3 882 000	5 824 000	7 982 000

To handle the materials in and out of these units as well as the various finishing facilities, it is necessary to provide within the plant 49 railroad engines per 8-h turn.

* Tons throughout the paper refer to net tons

TABLE I
Hot metal distribution

Open-hearth shop	No. of furnaces	Av. size of heat tapped, tons	Annual production, tons	Allocated hot metal, tons	Hot metal to ingot ratio
No. 1	14	167	1 745 000	1 150 000	0·658
No. 2	3	195	1 239 000	1 482 000	1·195
No. 3	14	150	1 768 000	1 140 000	0·646
No. 4	14	150	1 768 000	1 140 000	0·646
No. 5	6	185	953 000	617 000	0·646
	2	340	509 000	295 000	0·58
			7 982 000	5 824 000	

THE STEEL-PRODUCING DIVISION

In the steel-producing division a matter of extreme importance is the need for a continual supply and proper distribution of the available hot metal. With twelve blast furnaces in operation a daily production of about 16 000 tons is obtained. When casting on a 6-h cycle, a cast averaging 335 tons must be handled to some consuming point every 30 min. Of the 48 casts, 16 are blowing iron analysis and 32 are conventional basic iron. To distribute the optimum allotment of hot metal for maximum overall plant ingot production, each O H facility, with its limitation, is considered carefully for final metal allocation. All casts are first delivered to a hot-metal scale where they are weighed and distributed by an O H hot-metal dispatcher in accordance with individual shop needs. The present hot metal distribution based on the January 1st, 1959 availability is shown in Table I.

Hot metal production and distribution at Gary Works has been regulated for years with due regard for two main considerations, namely availability and price of purchased scrap, and the lack of a premium O H charge ore. In view of the company's policy to be as nearly self-contained on metallics as possible, it is necessary to provide sufficient hot metal for the purpose. However, in the absence of premium charge ore at an economical price, it is necessary to maintain the hot metal to ingot ratio at about 0·65 maximum in the stationary shops to attain optimum production. It is obvious that an alternative method must be developed of providing charge metallics for the

TABLE II
Annual net tons

Shop	Ingots	Cold iron	Hot metal	Metallics in ores	Metallics in additions	Customer and own revert	Outside purchased scrap
No. 1	1 745 000	76 000	1 150 000	160 000	18 000	645 000	4 000
No. 2	1 239 000	...	1 482 000	6 000	15 000	...	...
No. 3	1 768 000	77 000	1 140 000	150 000	30 000	653 000	5 000
No. 4	1 768 000	77 000	1 140 000	150 000	26 000	653 000	5 000
No. 5	953 000	41 000	617 000	80 000	12 000	352 000	3 000
	509 000	...	295 000	35 000	6 000	233 000	24 000
	7 982 000	271 000	5 824 000	581 000	107 000	2 536 000	41 000

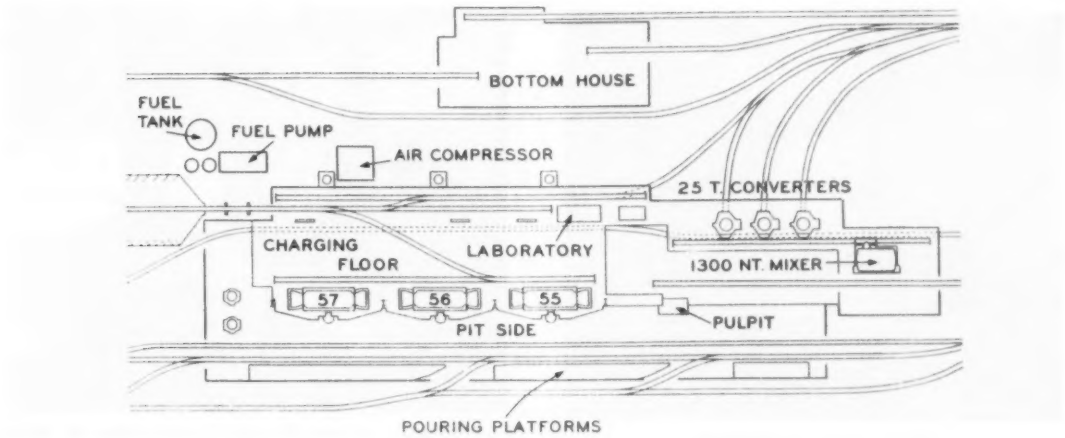


Fig. 2—Layout of facilities at No. 2 O H

stationary furnaces if self-sufficiency is to be maintained. No. 2 Shop becomes of prime importance in providing cold charge metallics as revert scrap from its own ingots meanwhile using little or no scrap in the charge.

From Table II it can be seen that No. 2 O H occupies a very prominent position in the Gary planning. If alternative methods are to be considered for steel production, any contemplated change in practice must give consideration to its function as a scrap producer or conversely as a source of hot metal for additional ingot tonnage.

PRESENT PRACTICE AT No. 2 OPEN HEARTH

The layout of No. 2 O H at Gary Steel Works is similar to other duplex O H shops of the United States Steel Corporation and is characterized by rapid material flow from the moment the hot metal is received in the mixer building until the ingots are withdrawn from the O H pit. Figure 2 shows the general arrangement of facilities. Hot metal is received at ground level in the mixer building and handled by crane for dumping into the mixer which has a capacity of 1 300 tons.

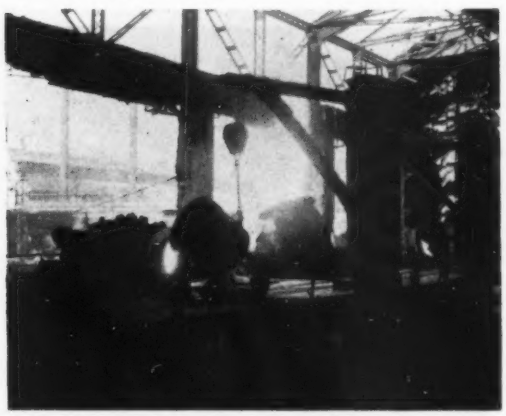


Fig. 3—Transfer of metal from ladle to vessel using jib cranes

When any one of the three Bessemer converters is ready for hot metal the mixers are turned and pour directly into a transfer ladle mounted on a cable-drawn car. The metal is transferred from the ladle into the vessel by means of jib cranes mounted on either side (Fig. 3). Movement of the cable-driven hot-metal car is controlled by the mixer operator while operation of the jib cranes is controlled from the blower's pulpit on the building wall opposite the vessels.

Air for blowing the converters is supplied by two reciprocating blowing engines. These provide sufficient air for blowing only 2 of the 3 vessels at any one time. Typical appearance of the converters from inside and outside the shop is visible in Figs. 4 and 5.

Three acid-Bessemer vessels, the noses of which are lined with Cleveland sandstone and the balance lined with micaschist for a lining thickness of 18–20 in., can make 25 tons of blown metal per blow. In turn the production of 2 vessels is handled in a single transfer ladle to the O H furnaces; thus 50-ton increments of blown metal are available. The ladles for transferring blown metal from the converter to the tilting furnaces (Fig. 6) are carried on ladle cars at ground level under the vessel platform. They are coupled to a locomotive through a series of coupling beams mounted between intermediate buggies. This allows the ladle cars to be spotted under any of the vessels without requiring a locomotive to enter the immediate area. They are transferred from cars to furnaces by crane (Fig. 7). Vessel slag is dumped into pans mounted on buggies which run on tracks leading to each vessel at right-angles to the single transfer car track.

Operating data for the Bessemer converter section is included in Table III.

Figure 8 shows the three tilting furnaces which are housed in the main shop building. These furnaces (Fig. 9) are each 84 ft 11 in. long at charging floor level and built on 115-ft centres with the furnace proper separated from the port ends by water-cooled chill plates. They have a hearth area of 863 ft². At a heat size of 195 tons, 4·45 ft² of hearth area/ton is available.

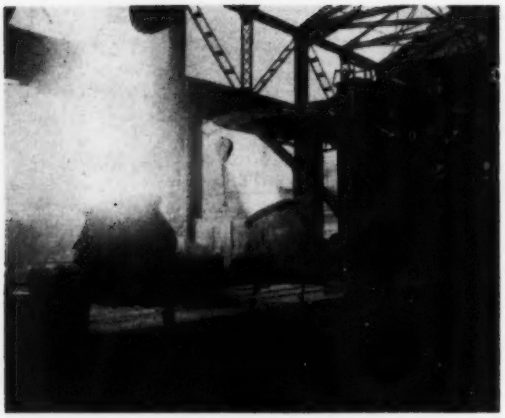


Fig. 4—View of converters

Fig. 6—Ladle for transferring blown metal to tilting furnace

The beams supporting the hearth are mounted on circular arc rockers and tilting is by means of an electrically driven screw assembly.

These tilting furnaces are constructed with silica roofs having 13·5-in. valley and 18-in. rib brick with 18-in. drop sections front and rear. Port roofs are 18-in. silica brick, port end walls are 9-in. basic brick, and side walls are 22·5-in. silica brick. Normal silica roof life is about 600 heats.

The regenerative system contains two checker chambers at each end of the furnace with 12·0-in. checker depth and 7 343 ft³ of checker brick at each end. Conventional silica brick arch construction is used to connect the checker chambers to the slag pockets. Water-cooled slide dampers are used in the flues for reversing the direction of gas flow.

The furnaces are not equipped with forced air fans or waste-heat boilers. As a result, air for combustion and draught for exhausting waste gases is obtained by natural draught.

For the purpose of making rapid comparisons of furnaces within the United States Steel Corporation a form called a 'furnace areagram' has been developed (Fig. 10) which displays pertinent furnace data adjacent to its location on a schematic drawing. While only a portion of the entire data is listed, major points are readily discernible. These areagrams are available for all of our furnaces and have been quite helpful for reference purposes when preparing for furnace changes.

Normal fuel for the shop consists of fuel oil and coke-oven gas with the latter as high as 28% of total fuel. Occasionally pitch tar is used in place of oil. Both fuel combinations are introduced in the same water-cooled combination burner (Fig. 11). Atomization of the liquid fuel is done with steam in an externally mounted atomizer (Fig. 12). The furnaces are equipped with necessary instruments for indicating or recording fuel flow, furnace pressure, steam pressure, checker temperature, etc. They are not equipped with automatic reversal systems at present.

Referring to the shop layout (Fig. 2) there is a lean-to adjacent to the charging floor from which one cross-over leads to the track in front of the furnaces. Limestone and feed ore are brought to the furnaces on this track. Two short stub-end tracks are provided in the lean-to for storage of buggies loaded with limestone and ore.

Standard operating practice for the open hearth is

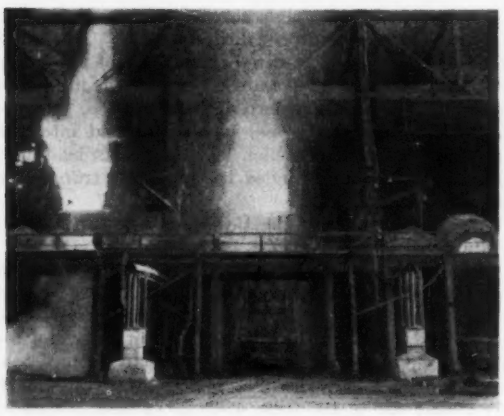


Fig. 5—View of converters

Fig. 7—Crane transferring ladle from car to furnace

TABLE III
Bessemer converter operating data Gary Steel Works No. 2 O H

	1955	1956	1957	1958
Hot metal, lb ton	2 201	2 230	2 249	2 253
Iron and steel scrap, lb ton	27	28	14	11
Gross metal, lb ton	2 228	2 258	2 263	2 264
Yield: blown metal, %	89·8	88·6	88·5	88·3
Tons Turn	884·4	987·8	827·3	856·1
No. of turns	1 086	948	974	1 063
Total tons	823 209	772 208	805 773	910 063

to charge limestone on the furnace bottom followed by blown metal from the converters. Usually 80 lb/ton of limestone is charged and 9–25 ton blows from the vessels. Sufficient quantity of hot metal is also added to provide a carbon content at melt about 0·40–0·50% above the desired tapping range.

With the practice which includes beneficial effects of a lime boil the heat is worked and shaped similar to any conventional stationary furnace heat after flush.

Tapping of the heat (Fig. 13) from the tilting furnace is accomplished in the conventional manner by rolling over the furnace. Problems with the taphole are at a minimum. Smooth taps with uniform metal flow and controlled amounts of slag in the ladle are normal. Conventional pouring techniques are used (Fig. 14).

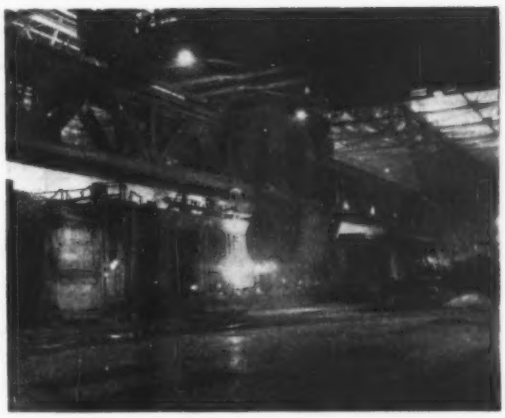


Fig. 8—General view of three tilting furnaces

A log of a typical heat including both Bessemer and tilting furnace practice is given in Table IV.

Through the use of the limestone boil final nitrogen content of the steel will be in the range 0·006–0·008%, and the product of the furnaces is suitable for all but the most severe forming grades.

A table of operating data (Table V) is given covering the years 1955–58. Attention is directed to the rather large production from a 3-furnace shop even at less than full operation. When peak production is required and sufficient hot metal is available, 413 000 tons of ingots can be produced yearly from each furnace by means of this practice. Operating rates

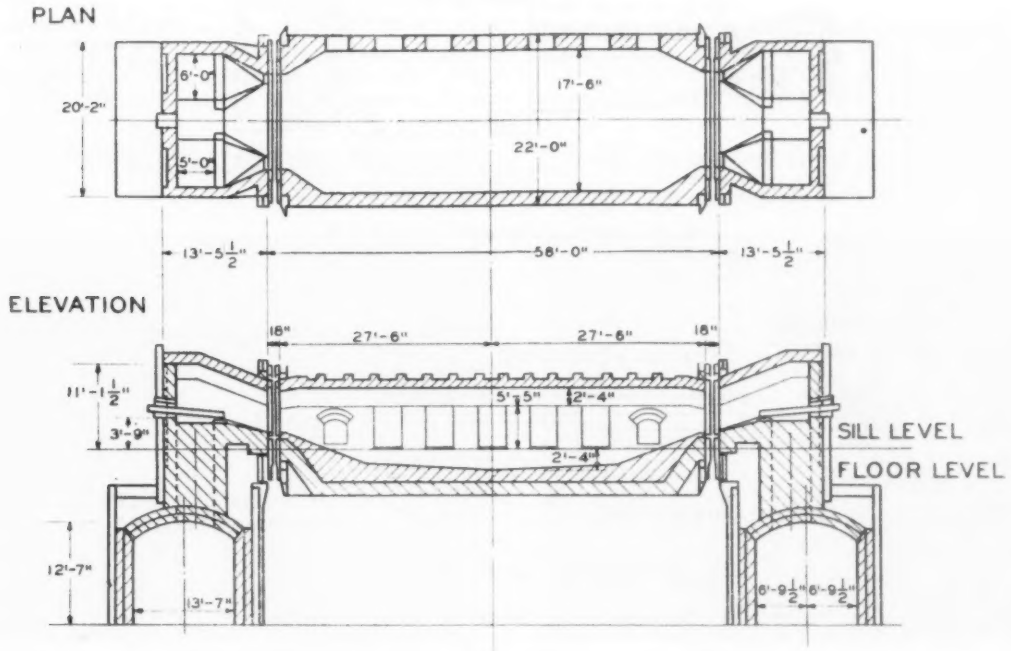


Fig. 9—Tilting furnace

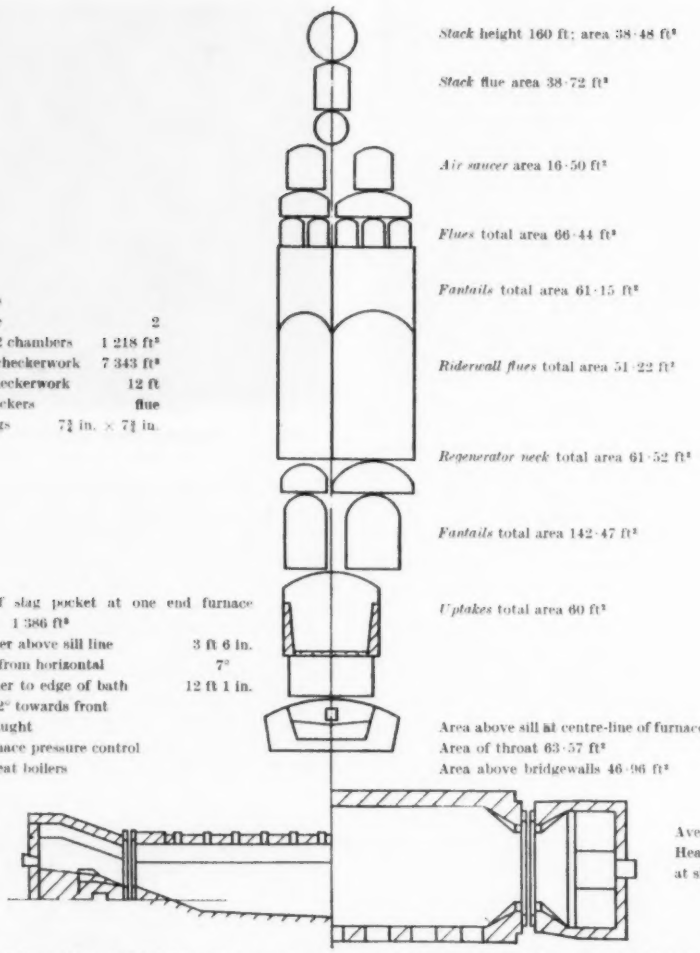

Stack height 160 ft; area 38·48 ft²
Stack flue area 38·72 ft²
Air saucer area 16·50 ft²
Flues total area 66·44 ft²
Fantails total area 61·15 ft²
Riderwall flues total area 51·22 ft²
Regenerator neck total area 61·52 ft²
Fantails total area 142·47 ft²
Uptakes total area 60 ft²
Area above sill at centre-line of furnace 128·6 ft²
Area of throat 63·57 ft²
Area above bridgewalls 46·96 ft²
Regenerators
No. per side 2
Volume of 2 chambers 1 218 ft³
Volume of checkerwork 7 343 ft³
Depth of checkerwork 12 ft
Type of checkers flue
Size openings 7¾ in. × 7¾ in.
Capacity of slag pocket at one end furnace 6 ft high 1 386 ft³
Tip of burner above sill line 3 ft 6 in.
Angularity from horizontal 7°
Tip of burner to edge of bath 12 ft 1 in.
Burner set 2° towards front
Natural draught
Manual furnace pressure control
No waste-heat boilers
Average heat size 190 tons
Hearth: inside brickwork
at sill line *length* 49 ft 4 in.
width 17 ft 6 in.
area 863 ft²
Information not included on the areagram
No. of uptakes (one end) 2
Internal diameter at bottom of stack 7·0 ft
Height above sill line: Centre of arch 7 ft 10 in., front skewback channel 5ft 3 in., rear skewback channel 5 ft 3 in.
Hearth area ft²/ton of ingot, 4·55
Slag pocket ft³/ton of ingot, 7·32

Fig. 10—Furnace areagram of No. 2 O H

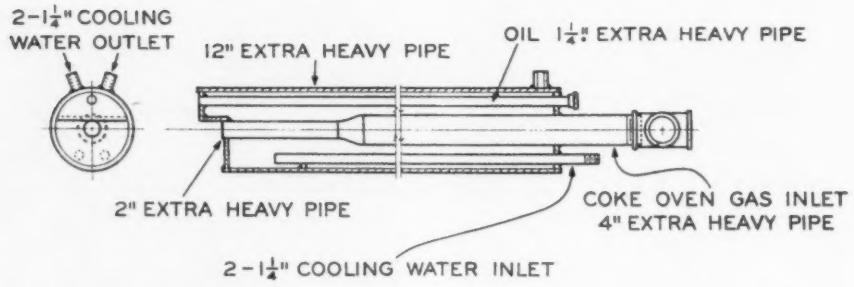

2–1¼" COOLING WATER OUTLET
12" EXTRA HEAVY PIPE
OIL 1¼" EXTRA HEAVY PIPE
2" EXTRA HEAVY PIPE
COKE OVEN GAS INLET
4" EXTRA HEAVY PIPE
2–1¼" COOLING WATER INLET

Fig. 11—Combination fuel burner, oil and coke-oven gas

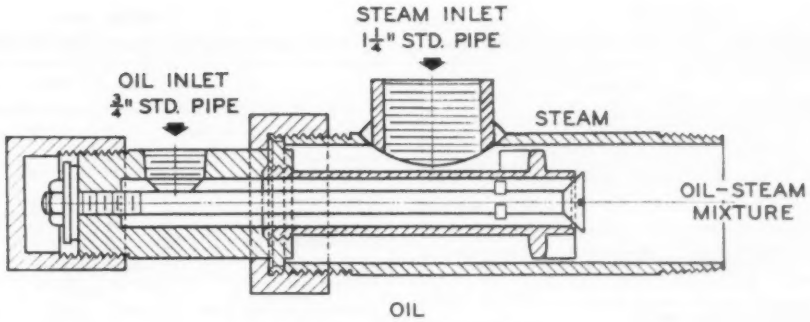


Fig. 12—Liquid fuel atomizer

in excess of 50 tons/h are normal. Such rates can be obtained only when sufficient facilities are available.

Sufficient auxiliary equipment has been provided for the mixer, Bessemer, and O H units:

1 100-ton Mixer crane
1 100-ton Converter crane
2 100-ton Hot metal cranes
2 7·5-ton Charging machines
2 175-ton Steel pouring cranes
1 100-ton Pit auxiliary crane.

Rapid as the pace is, sufficient time is required in the O H furnaces for removal of nitrogen and phosphorus. Meanwhile maximum charge in the bottom-blown vessels is 25 tons. The delivery of blown metal then is paced by both blowing time and ability of the furnaces to receive it. Finally, maximum production is limited by total availability of hot metal.

OXYGEN IN OPEN HEARTHS

For several years trials have been conducted in steel plants aimed at the economical use of oxygen for accelerating O H reactions. Its use to enrich combustion air in plants using high scrap charges or faced with regenerative system deficiencies is well known, but generally has been practiced only in periods of peak production. The price of oxygen must be considered to justify its use in normal periods.

In our plants oxygen has been introduced through tubes adjacent and parallel to the liquid fuel sources. These tubes are usually an integral part of the burner.

Oxygen introduced through door openings by submerged pipes has been quite successful for bath decarburization below 0·30%C. It is frequently and economically used in the production of the low-carbon grades where considerable increases in heat time may be required in absence of its use. Unfortunately, the occurrence of undesirable heavy fumes and associated furnace erosion have prevented such lancing at the higher carbon levels.

The use of water-cooled oxygen lances inserted through backwalls, frontwalls, corners, and finally furnace roofs has been tried over a period of time and has been generally unsuccessful due to heavy fuming, splashing, and furnace wear. However, in recent years a successful roof lance application was made by the Steel Company of Wales for decarburization of steels below 0·30%C.

In turn, following considerable investigation the United States Steel Corporation has developed a method of applying oxygen which allows the successful operation of one or more roof lances in a considerable number of our stationary O H furnaces. This is true even in the period immediately before, during, and after the hot metal addition to furnaces employing a hot metal to ingot ratio of 0·82 with the

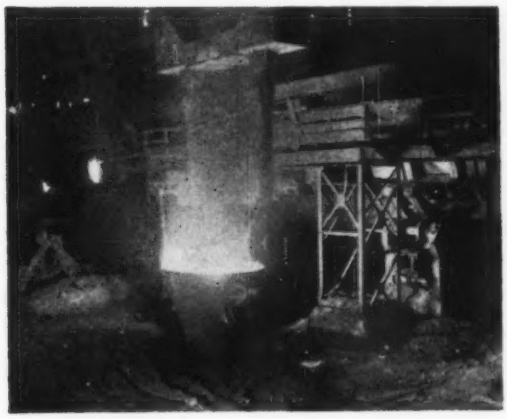


Fig. 13—Tapping the heat

Fig. 14—Use of conventional pouring techniques

TABLE IV

No. 2 O H, heat log of typical blown metal heat

Heat No. R-554508	Element, %				
	C	Mn	P	S	Si
Ordered analysis	0·06–0·08	0·33–0·43	0·030	0·035	0·02–0·00
Final analysis	0·08	0·43	0·010	0·020	0·006

Furnace charge	Blown metal 372 600 lb	Hot metal 30 000 lb	Limestone 18 000 lb

Time, a.m.

6 20 Tap previous heat
7 06 First Bessemer blow started
8 00 Last Bessemer blow finished
8 09 30 000 lb unblown hot metal
8 30 3 000 lb hard ore
9 00 1 500 lb hard ore
9 35 0·06%C; 0·02%Mn; 0·012%P, 0·024%S, 29·00%Fe in slag; V Ratio, 2·8
10 10 Tap ladle additions. 3 200 lb 80%FeMn, 125 lb Al Tap temperature 2 885° F
10 24 Begin pour. Nozzle, 2 in. Ingots produced, 397 744 lb ½ lb Al ingot
11 05 Finish pour

TABLE V

Furnace operating data Gary Steel Works No. 2 O H

		1955	1956	1957	1958
Limestone	lb/ton	78	72	82	73
Lime	,,	...	...	1	1
Fluorspar	,,	2	2	1	1
Total fluxes	,,	80	74	84	75
Magnesites	,,	1	2	2	2
Raw Dolomite	,,	31	24	34	24
Calcined Dolomite	,,	20	22	22	27
Misc. Refractories	,,	4	4	4	2
No. of heats		4 418	4 119	4 343	5 040
Av. heat size, tons		189·5	192·0	194·2	195·0
Times, tap-to-tap, h min		4 01	3 42	3 35	4 03
Tons operating h		47·20	51·92	54·21	48·15
Ingot yield, %		90·5	91·7	92·6	91·4
Ingots produced, tons		837 195	791 065	843 198	982 635
Actual operating time, % of possible		67·49	57·82	59·19	76·65

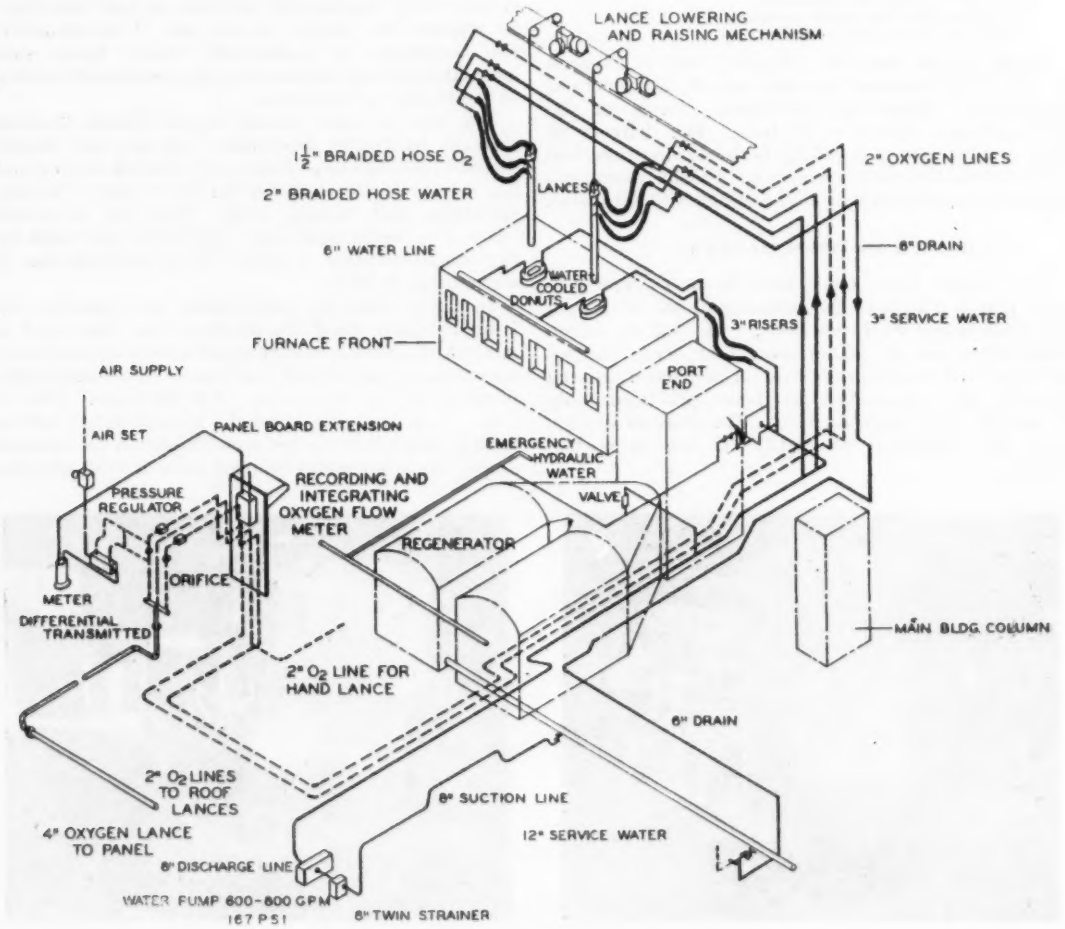


Fig. 15—Double oxygen lances, panel, piping, and hoists

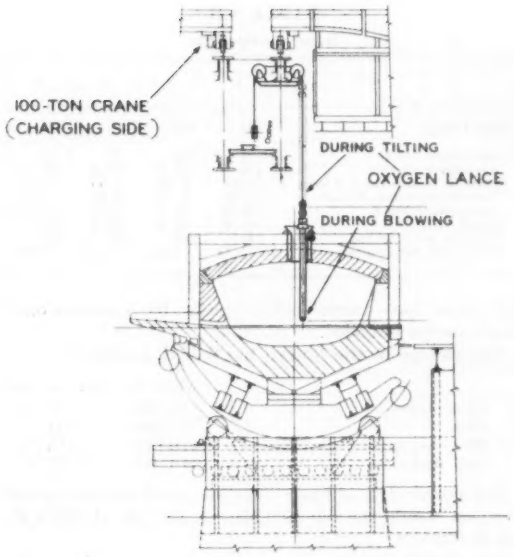


Fig. 16—190-ton tilting furnace with oxygen roof lance in position

accompanying heavy-charge ore burden. The use of this method has been included in our future plans for increasing tonnage from all our stationary O H shops and will be described in some detail later in this paper.

THE USE OF AN OXYGEN ROOF LANCE IN A TILTING O H FURNACE

At No. 2 O H, high-scrap charges are not used and the regenerative system is adequate; thus oxygen enrichment is unnecessary. Submerged lances have been used for decarburization of low-carbon steels for several years. In view of the current success with oxygen roof lances at several of the O H shops, including Gary No. 5, it is logical that a trial of a similar practice should be made in one of the tilting furnaces. The object of such trial would be to determine if extremely high basic hot-metal charges could be processed directly to ingots with oxygen roof lances at a favourable production rate and ingot cost compared with the conventional blown-metal practice.

Should the practice described prove practical it would eliminate the Bessemer converters and the need for low-Mn low-P blowing iron. It would result in the manufacture of a finished product of lower nitrogen content. The elimination of the converters and associated equipment would represent a saving if equivalent tonnage could be produced from the three furnaces. The substitution of basic iron for blowing iron would decrease the price of ore to the blast furnaces, meanwhile increasing production from the blast furnaces. The lower nitrogen content would permit more flexibility in product application.

No. 55 furnace was selected for the trial and the required piping, pumps, structural work, oxygen lines, etc. were designed and fabricated (Fig. 15). Some of the connections and controls were rather involved, but gave us little trouble. It was decided to locate the two lances (Fig. 16) about midway between the front and backwalls opposite the third and fifth doors of the seven-door furnace to provide for uniform oxygen distribution. Fabricated water coolers were installed in the roof to permit insertion and removal of the lances. Brackets for mounting sheaves, motors, piping, etc. were installed on the building structure above the furnace. Alterations were made to the sill plates in the front of the furnaces at the second and sixth doors, to permit front flushing of the large amounts of slag experienced with high-metal charges.

The lances used (Fig. 17) contain six oxygen outlets 0·5 in. dia. at 30° from the vertical. Their heads are fabricated from copper with the balance steel.

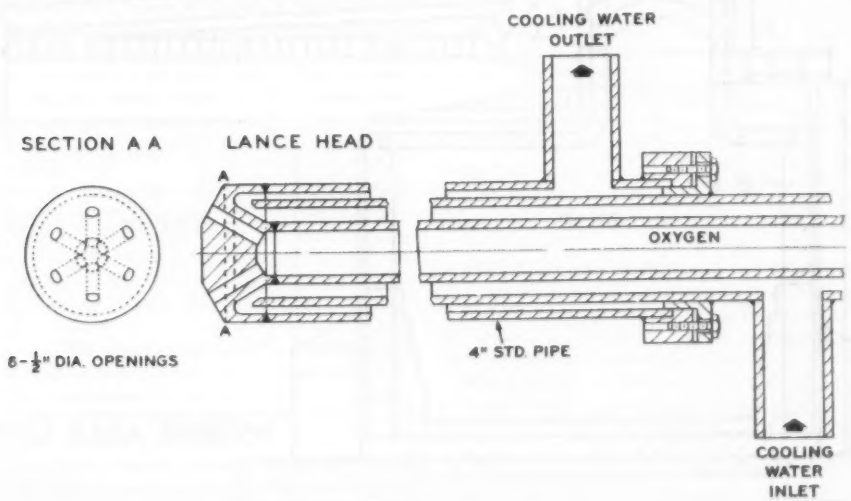


Fig. 17—Oxygen roof lance

TABLE VI
Distribution of lanced heats

Campaign	Furnace on	Furnace off	Total heats produced	No. of roof-lanced heats	No. of conventional heats
1	5-12-57	2-2-58	351	21	330
2	13-2-58	25-3-58	142	124	18
3	29-3-58	25-4-58	90	77	13
4	2-5-58	1-6-58	173	20	153

TABLE VII
Roof campaign

	1	2	3	4
Total Heats	351	142	90	173
Roof-lanced heats	21	124	77	20
Average heat size	190·3	189·9	189·4	189·3
Charge-to-tap time, h min	6 00	6 15	6 55	7 04
Tap-to-tap time, h min	6 41	7 17	8 01	7 56
Tons/operating h	28·5	26·0	23·6	24·2
Yield, %	81·0	81·0	80·1	82·1
Oxygen used, ft³/ton	732	862	887	873
Fuel used, 10^6 Btu/ton	2·74	2·43	2·30	2·10

Cooling water at 125 lb/in² and oxygen at 150 lb/in² are available at the lance.

The equipment was installed and changes made when the furnace was shut down for a ground level rebuild. Following completion of the work, the furnace was placed back in operation on 5th December, 1957.

During the first five days of the initial campaign, conventional liquid metal heats were produced. The first heat employing roof lances and scrap, ore, hot metal charges was made on 11th December, 1957. Thereafter until the end of the roof campaign, lanced heats were produced on day turn only with those on the other two turns being made by conventional blown-metal practice.

The charge in the lanced heats was as follows:

	Weight, lb	*lb/ton of ingots*
Limestone	15 000	79·0
Ore	75 000	381·0
Steel scrap	110 000	513·0
Hot metal	310 000	1 716·0

Our conventional basic iron was used and a typical analysis would be: 2·20%Mn, 1·15%Si, 0·270%P, and 0·030%S.

About 75% of the limestone was charged on the bottom followed by half the ore. The balance of

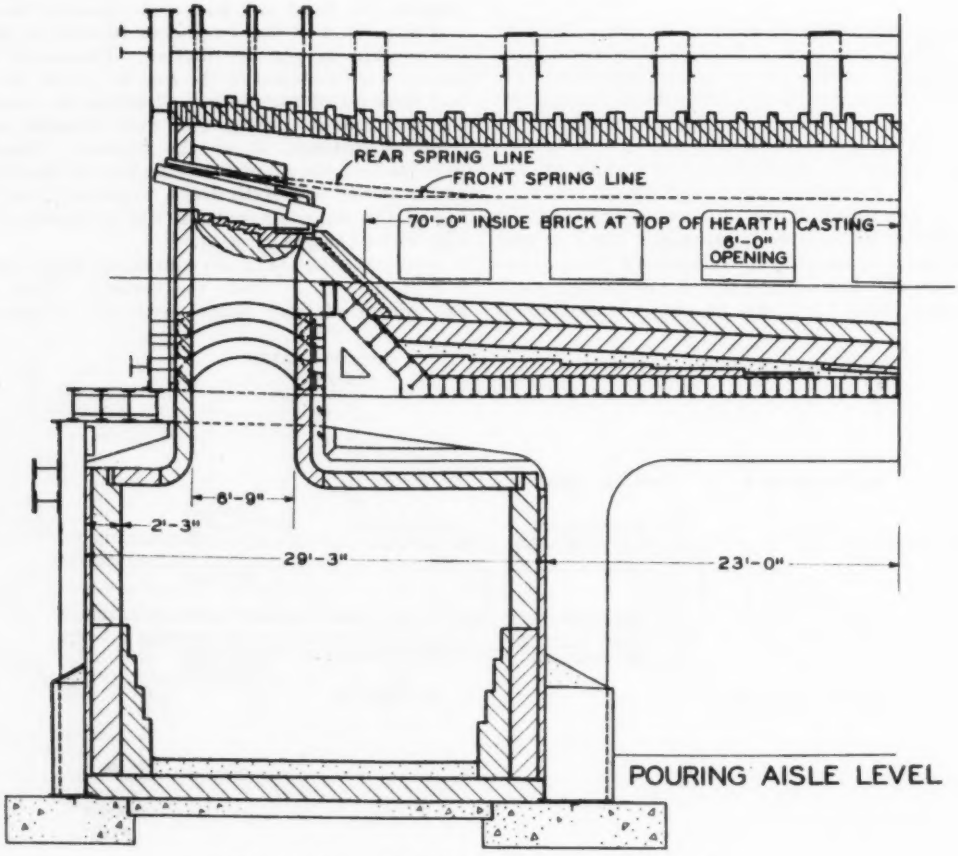


Fig. 18—Proposed 380-ton furnace, half elevation

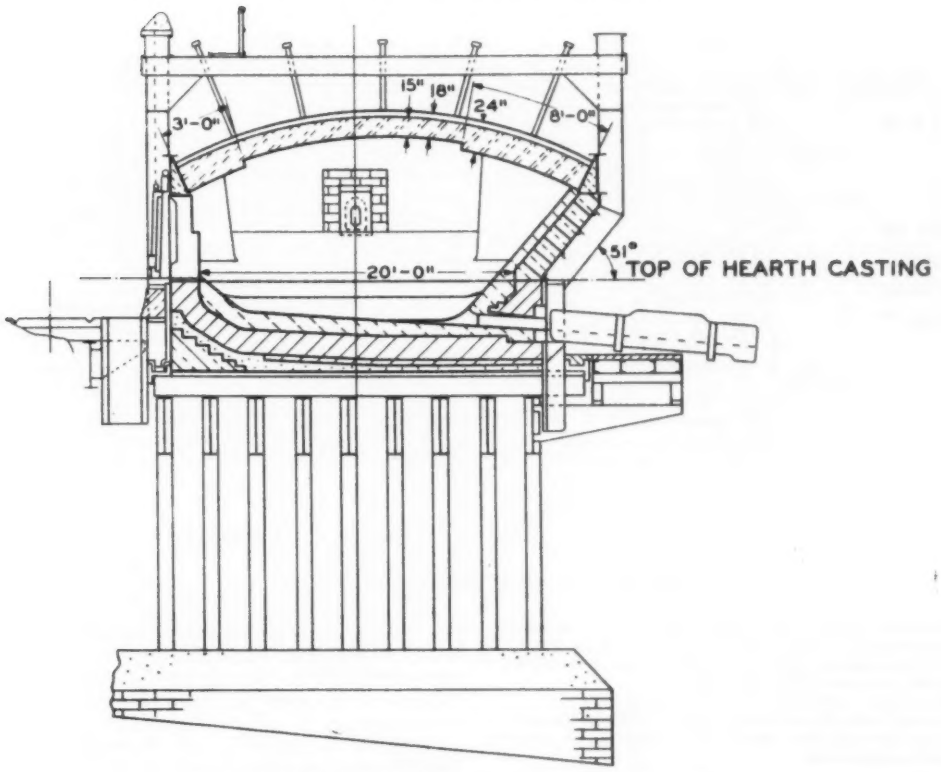


Fig. 19—Proposed 380-ton furnace, section at centreline

the limestone and ore was then added after which the steel scrap was charged. Doors were then banked and the hot metal addition made as soon as possible. Flushing began immediately and flowed to the ground over the front.

Oxygen flow through each of the two lances was started as soon as scrap was charged at the rate of 20 000 ft³/h/lance. During the hot metal addition, oxygen was turned off and was resumed only after the violent bath action had subsided. This period usually continued for about a half an hour after the addition. The oxygen rate when again in operation was unchanged at 20 000 ft³/h/lance and was maintained till tapping.

Observations of the silica roof during the first campaign showed that roof lancing would have a detrimental effect. Although only 21 heats were lanced during this campaign it was necessary to replace the roof after 351 heats. This compares to an average silica roof life at No. 2 O H for 1958 of 581 heats/roof.

In addition to the lower roof life the slag pocket accumulation was much greater than normally experienced. The combination of lower roof life and slag pocket accumulation would reduce overall furnace availability.

Additional problems developed which made operations more difficult than conventional practice and operating statistics of the four campaigns show a considerable drop in production from normal practice. Some of the reasons for this are concerned with equipment limitations and are listed as follows:

(i) Metal delays due to simultaneous handling of basic and blowing iron
(ii) Interference with vessel blowing while transferring basic iron at the auxiliary pit
(iii) Cold stock delays from loading at remote locations in absence of stockyard facilities for No. 2 O H
(iv) Limited trackage for switching buggies adjacent to No. 55 Furnace
(v) Occasional delays occurred from inability to remove flush slag in available time interval
(vi) Charge oxides provided were not suited to high metal charges. High silica and low bulk density caused considerable overflow and yield loss.

During the second and third roof campaigns lanced heats were produced on a twenty-four hour basis with relatively few liquid metal heats included. In the fourth campaign twenty lanced heats were produced in the early part of the campaign but thereafter all heats were standard liquid metal heats.

Distribution of lanced heats in the four campaigns are shown in Table VI. The operating statistics of the roof-lanced heats are shown in Table VII.

When results of the trials are compared to statistics of heats made to normal liquid metal practice the results may best be summarized as follows:

(i) Overall yield of charged metallics to ingots reduced by 2·1%
(ii) Production rate reduced by 50%
(iii) Potential annual production reduced by at least 50%

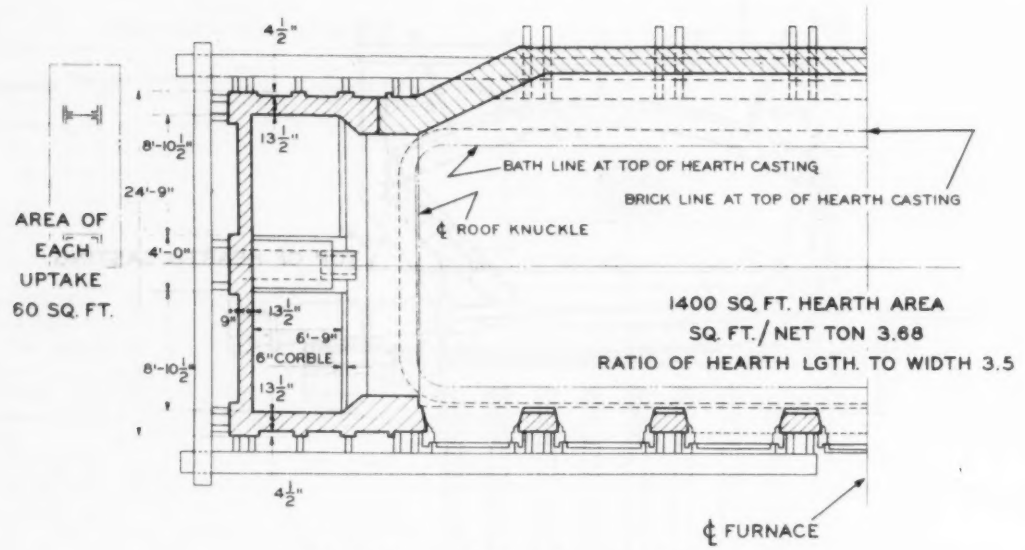


Fig. 20—Proposed 380-ton furnace, half plan

(iv) Furnace repair and maintenance costs increased appreciably. The exact amount would have to be determined over a period of time, but appears to be at least a 100% increase
(v) Fuel costs increased by 75% minimum
(vi) Overall cost of producing ingots increased appreciably through the significant lowering of overall shop production.

With the combination of high cost and reduced tonnage the lance practice in the tilting furnace shop with present equipment and layout becomes quite unattractive. However, in view of current results in the large stationary furnaces employing this practice, a second look was taken at No. 2 O H to reassess its possibilities with properly designed furnaces and necessary auxiliary facilities.

THE INSTALLATION OF MODERN STATIONARY O H FURNACES IN No. 2 O H

In view of the current excellent results being obtained in several of the large modern O H shops when a proper relationship of furnace design, charge metallics, and oxygen practice is used, a careful examination was made of an alternative method by which Gary No. 2 O H could be used to provide both necessary ingot tonnage and hot metal for equivalent or additional ingot tonnage for the plant.

Any altered or new operations considered must fulfil the following minimum requirements:

(i) A production rate of at least 42 tons/h
(ii) A furnace availability of at least 95·0% in order that a minimum annual production of 350 000 tons/furnace/year can be maintained
(iii) The ability to utilize conventional basic iron and available O H charge ores in order to show a favourable cost reduction versus the present duplex process employing low-Mn low-P ores through the blast furnaces.

Since the present tilting furnaces are constructed on 115·0-in. centres, it is possible to install large stationary O H furnaces with adequate regenerative systems. Because of the limitation of the present pit building to heats of 180 tons maximum, and the heavy expenditure required to enlarge its capacity appreciably, the furnace would of necessity be required to tap into two ladles by means of a bifurcated spout.

A suitable furnace has been designed (Figs. 18–20). With hearth dimensions inside brickwork of 70 ft long by 20 ft wide, this furnace would provide 1 400 ft² of hearth area. At a heat size of 380 tons, a hearth area of 3·68 ft²/ton would be available and is considered quite adequate. Necessary charging machines, cranes, and auxiliary facilities would be provided for maximum production rates. Present hot-metal handling facilities would be maintained and are considered quite adequate for the reduced hot-metal charges. Necessary stockyard facilities would be provided either as new facilities or through use of present No. 1 stockyard in the event that it should be no longer required for its present service.

To handle the increased amount of cold metallics additional track lengths would be provided, for charging cars, as extensions of present tracks before the furnaces. At least one more crossover would be added to improve accessibility.

Each of the furnaces would be equipped with front flush arrangement to enable an efficient, rapid removal of slag from the furnace. At the same time metal losses would be minimized by locating furnace personnel at the furnace front in the proper location during flushing to observe the runoff.

With the new furnaces and auxiliary facilities the three required advantages can definitely be obtained when two current practices are also installed.

Each of the furnaces would be equipped with suitable burners including oxygen for air enrichment during meltdown and two oxygen roof lances for decarburization similar to those installed for the trial on the tilting furnace. Each of the lances would contain six openings at 20° or 30° from the vertical.

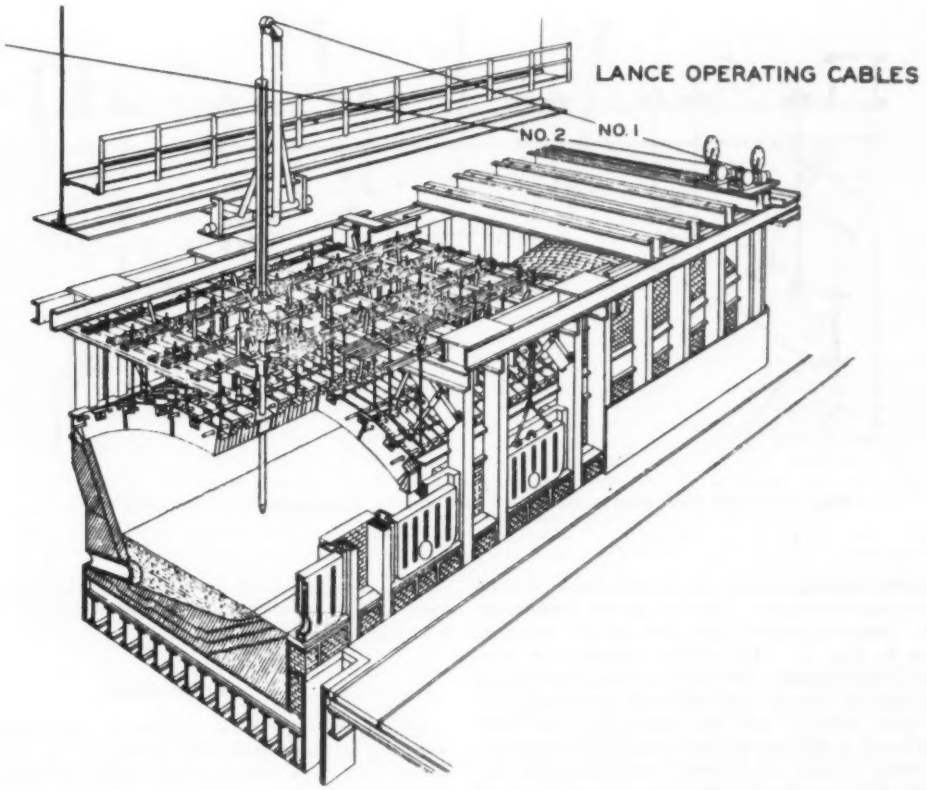


Fig. 21—Basic O H furnace at the Fairless Works with suspended basic roof and oxygen lance

The openings would range in size from $\frac{7}{16}$ to $\frac{9}{16}$ in. The exact angle and opening would be determined by optimum furnace operation and minimum splash. Based on our past practices a total of about 150 ft³ of oxygen/ton would be used for combustion during meltdown and 450 ft³/ton for decarburization. Assume a heat cycle as follows:

Start charge to finish charge cold metallics	1·25 h
Start charge to finish hot metal	2·25 h
Start charge to tap	7·25 h

Oxygen for combustion improvement would be used for 2·5 h at a rate of 20 000 ft³/h. Lance oxygen would be initiated after hot-metal addition and would be used at a rate of about 20 000 ft³/h/lance. Lance openings and flow rates would be selected to provide outlet velocities in the 400–1 100 ft/s range.

By use of the practice outlined above we have demonstrated on many occasions that properly serviced furnaces can produce heats in about 8-h tap-to-tap time or at least 42 tons/h in a 380-ton furnace.

Through the simultaneous use of a second practice which has recently been developed for application in our furnaces, any reduced furnace availability from the oxygen lance practice is overcome. In fact a future furnace availability of 94–96% depending on individual shop conditions can be provided through the installation of the sprung basic roof with the added design features of rigid holdups and holddowns.

For illustration of the lance practice and basic roof design, a Fairless Works furnace is selected because it best represents the furnace size and operating rate required for our planned furnaces in No. 2 O H, Gary Works. Figure 21 is a sketch showing a Fairless furnace which includes the two oxygen roof lances and sprung basic roof.

The oxygen roof lances formed with a copper head about 6 in. long and the balance steel contain six $\frac{1}{2}$-in. dia. holes at 20° from the vertical, arranged symmetrically about the vertical axis. Oxygen is introduced at a rate of 20 000 ft³/h/lance beginning immediately after hot metal addition and continuing until the desired carbon level has been reached, usually in about 4 h.

The main features of the roof design include the use of four 12-in. thick valley and two 15-in. thick rib courses of chemically bonded internally and externally plated basic brick. These bricks are 12 × 4·5 × 3 in. and 15 × 4·5 × 3 in. in size and are laid with the 4·5 in. dimension forming the roof rings.

Placed between the rib rings and the centre-valley rings (Fig. 22) are $\frac{3}{16}$-in. steel plates cut in 5 sections to fit the roof contour from front to rear skewback. These are individually hung from furnace steelwork

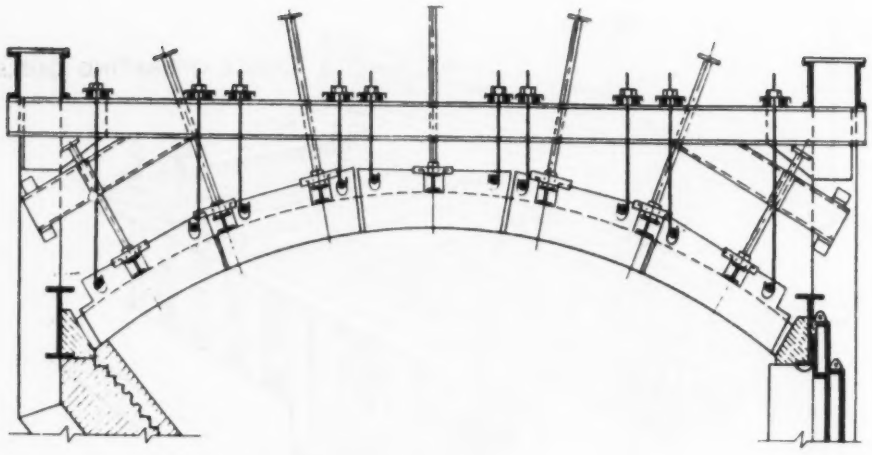


Fig. 22—Basic roof (Fairless Works) with details of suspensions and holddowns

and also tied together above the horizontal holddown beams, by steel sections. The use of the holddowns and 6-in. beams to which they are tightly attached is shown in Fig. 22. The entire construction provides maximum rigidity, for once the brick and plates are installed the centres are removed permitting the roof to drop slightly and the holddowns are then adjusted to the holddown beams as tightly as possible.

Our initial furnace at Fairless equipped with this roof design and the oxygen roof lances gave excellent results during early 1958. A few details follow:

Initial campaign, Fairless Works oxygen lance and basic roof practice

No. of heats per roof campaign	368
Av. heat size, tons	342
Total tons produced	126 052
Tap-to-tap time, h min	7 59
Tons/operating hour	43·04
Hot metal to ingot ratio	0·735
Furnace yield, %	85·5
Fuel rate, 10^6 Btu/ton	2 350
O_2, ft^3/ton	439

Following the initial run on Fairless No. 2 furnace several additional roof campaigns have been completed on other furnaces employing the same lance practice and roof construction. Operating results have been similar and the roof life has reached 399 heats. In view of the fact that 206 heats represented a breakeven point with former silica roofs, the present life is quite attractive. All furnaces at Fairless Works are now equipped with roof lances and basic roofs.

Many of our furnaces in other plants are also equipped with similar lances and basic roofs. To date we have used several different types of brick. These include the lower magnesia 45% and higher magnesia 65% both of the chemically bonded type and internally and externally plated. Future work will include trials of burned brick as well as chemically bonded without internal plates.

We consider the oxygen roof lance practice and the sprung, suspended basic roof with holddowns to be two of the most significant developments for O H furnaces in recent years.

CONCLUSIONS

Of the three methods studied for replacing or augmenting tonnage presently produced in No. 2 O H Shop, two have been proved quite practical, and a third has been unsatisfactory.

Additional tonnage can be produced in existing equipment when improved auxiliary facilities and increased hot metal are made available. With a constant hot metal output, ingot tonnage would be restricted to the present level.

The trials of vertical oxygen lancing high hot-metal charges in the present tilting furnaces were not satisfactory. Charge ores available are not of sufficient quality for such practice. Production rates obtained were not sufficient to replace existing tonnage.

By replacing present tilting furnaces with large double-heat stationary furnaces equipped with basic roofs and vertical oxygen roof lances, nearly equivalent total shop tonnage can be produced from three furnaces; in fact, by addition of a fourth furnace, greater tonnage could be produced. Meanwhile, a low hot-metal charge can be used eliminating the need for premium charge ores and providing a supply of hot metal for other O H operations. Simultaneously, the need for the Bessemer vessels would be eliminated with resulting economies.

The current use of basic roofs and vertical oxygen roof lances is, we believe, a most significant step in the future progress of O H furnaces.

ACKNOWLEDGMENTS

I would like to express my appreciation to Mr S. M. Jenks for his counsel in preparation of this presentation; also to Mr J. J. Golden and Mr C. M. Kay for their aid in preparation of the paper.

Some investigations on the treatment of molten iron

By W. J. B. Chater, M.A.(Cantab.)
and J. A. Charles, B.Sc., A.R.S.M., A.I.M., A.M.I.M.M.

SYNOPSIS

An account is given of the small-scale investigations on oxygen pretreatment processes at the British Oxygen Research and Development Ltd. Operative variables in normal ladle treatment with oxygen were investigated, including the effect of surface slag-making additions under both acidic and basic conditions. The work on oxygen pretreatment with slag-making materials dispensed as powders in the oxygen stream is also described, as is the development of the ' tower process ' for pretreatment.

The treatment of iron for desulphurization and carburization before foundry use with dispensed powders is described, also the recent work on the injection of oxygen into the hearth of a cupolette enabling higher temperatures and higher-carbon metal to be obtained from an all-scrap charge. 1695

INTRODUCTION

IN RECENT YEARS much attention has been given to the desiliconizing of blast-furnace iron with oxygen to obtain increased productivity in basic open-hearth furnaces or in basic Bessemer converters. This is particularly so in the open hearth, where it has been found necessary to increase the proportion of hot metal in the charge. Increased metalloid content in the OH charge leads to increased refining time, larger slag bulk, increased refractory wear, decreased efficiency in heat transfer from the flame to the metal, and higher fuel consumption. In the basic converter process an increase of silicon content in the iron charge causes increased slopping and ejection during the blow, with less control and decreased economy of operation.

The effect of silicon content in the hot-metal charge on the OH production rate has been demonstrated by various authorities, amongst them Wheaton,[1] Elam,[2] and Jackson.[3] Marshall[4] produced figures demonstrating the effect of slag bulk on production rate at the Park Gate Iron and Steel Co. where an increase in slag bulk from 11% to 21% decreased the output rate from 6·0 to 5·0 tons/furnace hour. This consideration by Marshall does, of course, cover variation in the phosphorus content of the charge as well as the silicon, both factors being found to have a significant effect on the productivity.

At the present there is also increasing interest in phosphorus removal from iron for subsequent foundry use as the proportion of low-phosphorus cast products increases. In this case, of course, the retention of carbon at the same time as the removal of phosphorus is of prime importance.

Pretreatment for silicon and phosphorus removal using oxygen has been effected in many ways; by normal ladle treatment in which oxygen is lanced or jetted into a full ladle, ladle treatment in which oxygen is jetted or lanced during the filling of the ladle, continuous treatment in a launder or chamber through which the iron is flowing (e.g. blast-furnace runner), treatment in rotary vessels (e.g. Rotor), and by lancing or jetting in existing active mixers. Although the fundamental reactions taking place are the same, various systems which have been employed can significantly affect the overall result obtained. For example, the nature of the containing vessel (i.e. its shape, the presence or absence of motion) and the method of oxygen introduction largely control the opportunity for adequate mixing of the vessel contents. Mixing prevents stratification of metal composition and temperature and promotes early slag formation and slag/metal contact. Stratification will reduce the speed and efficiency of desiliconization, whilst slag/metal contact is particularly important when phosphorus removal is required. By early slag formation and good slag/metal contact dephosphorization can be advanced relative to the removal of silicon and carbon. Further, there is the variation in the extent of conservation of the heat liberated by the oxidation reactions taking place to give higher metal temperature.

Our early efforts on oxygen in steelmaking were confined to giving assistance to steelmakers during trials in their works, during the period when we and they were becoming increasingly aware of the potential value of oxygen for increased productivity. The experience gained and our continual examination of technical literature led us to present general surveys of the subject[5, 6] and a detailed survey in the form of the first complete book on the applications of oxygen in iron and steel production[7] in co-operation with our colleague J. L. Harrison of British Oxygen Gases Ltd.

Experimentation in steelworks had shown the need for basic data in many of the oxygen applications and for facilities to carry out a greater number of experiments, not interfering with production, where a greater number of intermediate records could be made within the course of any one experiment. A research foundry was therefore established at BORAD where the major effort during the last five years has been on investigations of pretreatment processes. The choice of this field of research was

Manuscript received on 19th February, 1959.
The authors are with the British Oxygen Research and Development Ltd.

made because of its intrinsic importance and of the need for further information.

The aim has been to increase the attraction of the process metallurgically, i.e. to control, as far as possible, the order in which the oxidation reactions occur (e.g. the early removal of phosphorus and the retention of a higher carbon content at the end of the pretreatment operation), and to modify existing systems or develop new systems to achieve lower operation cost. In this latter direction high efficiency of oxygen consumption in relation to the degree of metalloid oxidation achieved, high yield of iron, low maintenance requirements, and the production of slags suitable for sale as fertilizer where possible have all been important objects of the work.

It has been recognized that a major problem to be dealt with in this as in other oxygen applications is the iron oxide fume formed. Initially, work on this subject was confined to the determination of processes which would give acceptable fume removal, some of which has been published,[8, 9] but more recently the emphasis has been on understanding how the fume is formed and devising means for preventing its formation. This later stage of the fume work is described by our colleague K. H. Sargent in another paper to be published shortly.

The treatment of iron for sulphur removal has been actively investigated by BORAD, although in this case not mainly as a pretreatment process in steelmaking, but as a conditioning treatment for foundry iron. In this field, work has also been carried out on carburizing techniques using dispensed carbonaceous powders and our interest in foundry iron is also reflected in a current investigation on the use of oxygen injection into cupola hearths for increased metal temperature and carbon pickup.

The subject matter of this paper is divided as follows:

Iron pretreatment processes as preceding steelmaking operations

(i) Investigation of ladle treatment methods with normal methods of slagmaking material addition

(ii) Pretreatment with slagmaking materials dispensed as powders, known as the 'powder pretreatment process'

(iii) Development of the BORAD tower pretreatment process.

Treatment of foundry iron

(i) Desulphurization

(ii) Increasing the carbon content of foundry melts

(iii) Oxygen lancing in the cupola hearth.

IRON PRETREATMENT PROCESSES

(i) Normal ladle treatment methods

Much of our work in this field has already been reported elsewhere.[7, 10] Two types of vessel were employed, using 120–130 lb iron; initially a normal hand-shank open ladle provided with a refractory-lined domed lid and subsequently, for the greater part of the work, a specially designed bogey-mounted tilting ladle of converter shape.

Without any slagmaking additions and employing an acid-lined ladle (ganister) the effect of the method, rate, and continuity of oxygen introduction on the silicon removal were investigated. Later the effect of slagmaking additions to the melt surface, under both acid and basic (dolomite) vessel lining conditions, on the degree of silicon and phosphorus removal achieved were also studied.

Method of oxygen introduction

This phase of the work was carried out in the hand-shank open ladle using hematite iron (2·5%Si, 0·8%Mn). The methods of oxygen introduction compared were: (*a*) lancing beneath the metal surface with $\frac{5}{16}$-in. bore steel pipe, (*b*) jetting on to the metal surface using pipe of the same bore, protected with a suitable refractory coating, and (*c*) jetting with a $\frac{7}{64}$-in. parallel bore nozzle and with an 0·076-in. throat convergent-divergent nozzle, these also being protected with refractory. All experiments were carried out at an oxygen flow rate of 10 ft³/min, as under this condition the three jetting methods gave subsonic, sonic, and supersonic oxygen jets respectively.

Although the difference between the jetting methods was not as great as might have been expected, in high silicon ranges (above 1·8%) the use of the low-velocity jetting method (i.e. using $\frac{5}{16}$-in. bore pipe) gave slightly higher efficiency of oxygen utilization (i.e. quicker arrival at a required silicon concentration with less oxygen consumed) than the other methods. With decreasing silicon concentration high-velocity jetting became more efficient until at low levels the supersonic jet gave the best results. The variation in oxygen utilization for silicon removal that results from the use of the different jetting velocity appears to be directly connected with the two factors, penetration area and penetration depth. In the initial stages of blowing at high silicon concentration the governing factor is the area of penetration, since the metalloid concentration at the surface and the diffusion potential towards the surface is still high. In the later stages of silicon removal turbulence becomes of greatest importance so that the metalloids can be continuously brought into the zone of reaction. This turbulence occurs to a greater extent with the high-velocity oxygen streams which penetrate more deeply. At the same time there is an increased tendency to greater metal loss by ejection and spillage with reduced metal yield unless the freeboard on the ladle is increased, and even then the upper parts of the lining can become heavily encrusted. The carbon loss accompanying desiliconizing also appeared to be greater with increased jetting velocity, although the results were not wholly conclusive in this direction.

When lancing beneath the iron surface with the uncoated steel pipe the initial desiliconizing efficiency was higher than either sonic or supersonic jetting, although not as high as with subsonic jetting, and the efficiency remained more constant over the complete range of silicon removal investigated, as might be expected.

Figures 1 and 2 show the curves prepared for two of these conditions, lancing beneath the surface and jetting with $\frac{5}{16}$-in. bore pipe. The curves represent the average composition with regard to silicon, carbon, and manganese for numerous heats under each condition. In this and the subsequent work described in this section all the melts were weighed and the

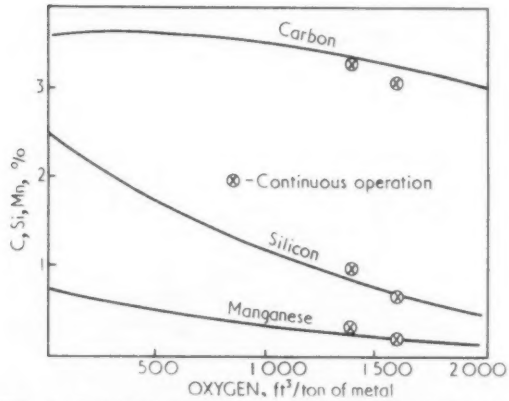


Fig. 1—Lancing with $\frac{5}{16}$-in. bore mild-steel pipe, oxygen flow rate 10 ft³/min, low-phosphorus iron, at 1 150–1 200° C starting temperature

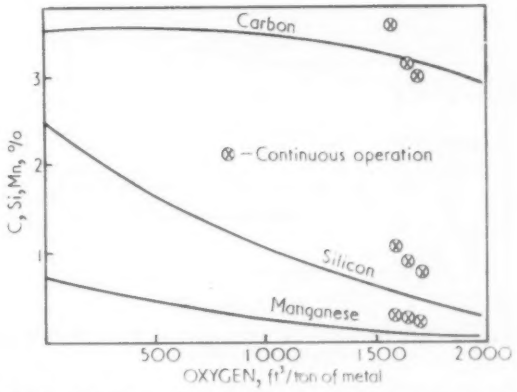


Fig. 2—Jetting with $\frac{5}{16}$-in. bore pipe, oxygen flow rate 10 ft³/min, 1 cwt low-phosphorus iron at 1 150–1 200° C

quantity and flow rate of oxygen employed metered throughout. The average blown weight, from which was derived the specific oxygen consumption (ft³/ton), was calculated assuming all metal losses (fume, slag formed, spill, samples, etc.) took place at a steady rate throughout. Where lance was consumed allowance was also made for this addition to the overall mass. Both sets of curves represent discontinuous operation with intervals for stirring and metal and slag sampling to give an average of four separate analysis results during the progress of each heat. The starting temperatures indicated are somewhat lower than normal for blast-furnace iron but quickly rose during the early stages of silicon removal, so that while the heat was in the normal silicon ranges for blast-furnace irons the iron temperatures were also of the same order. In other words, a higher silicon iron was employed to raise the temperature sufficiently by desiliconization by the time the normal silicon ranges were reached. In fact, however, subsequent work on the effect of oxygen input rate suggested that metal temperature did not have any significant effect on the rate of silicon removal.

Rate of oxygen introduction

Using the same iron as in the investigations on the oxygen introduction method, but with the bogey-mounted tilting converter-shaped ladle, tests were carried out on the effect of specific oxygen input rate. As previously noted, the standard oxygen input rate was 10 ft³/min, or about 200 ft³/min/ton. Using both lances and jets of $\frac{5}{16}$ in. bore the effect of reducing the input rate to 133 ft³/min/ton and raising it to 400 and then to 600 ft³/min/ton was investigated. At the reduced oxygen input rate the heat losses on this small scale with the particular vessel lining used exceeded the heat gained by reaction and operation was impracticable. With the higher oxygen input rates the process remained under complete control and although the metal temperature was higher (shorter blowing time, thus reduced heat loss from the vessel) there was no effect on the desiliconization efficiency expressed as silicon removed for a given oxygen input.

Continuity of oxygen introduction and melt stratification

The occurrence of metal composition and temperature stratification was quickly noted, particularly in melts blown with oxygen at low velocities. It was thus anticipated that where the progress of a jetting operation was interrupted for sampling and temperature measurement higher desiliconization efficiencies might result than where the blow was continued uninterrupted for the same total blowing period. With interrupted blows the silicon potential in the metal adjacent to the point of oxygen introduction would be raised by diffusion and the mechanical agitation involved in sampling. This was shown to be true, and although the differences were not great, in terms of the amount of silicon removed for a given quantity of oxygen introduced, continuous operation generally resulted in less efficient desiliconization than where the blow was interrupted. The effect was relative to the amount of turbulence created in the melt by the oxygen stream, being worst in the case of the $\frac{5}{16}$-in. jet. The results of the three continuous blows carried out under this condition are indicated by single points in Fig. 2 and in the case of the silicon and manganese results the final contents are considerably higher than the average represented by the curve. With the more general agitation caused by lancing stratification did not occur and there was no difference between continuous and discontinuous operation as regards the final silicon content (see individual points on Fig. 1).

Effect of slagmaking additions to the melt surface with ganister-lined ladle

Surface additions of slagmaking materials were made to investigate the effect on the efficiency of silicon removal, and in the hope of simultaneously removing phosphorus. The normal dephosphorizing slag consisting basically of iron oxide and lime would obviously result in serious lining attack under acid conditions, with reduction in slag basicity and dephosphorizing power, the effect increasing with temperature. For this reason interest was mainly centred on soda ash, which is generally considered a more stable dephosphorizing agent in the presence

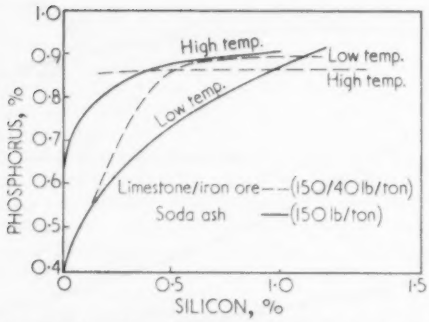


Fig. 3—Relationship between silicon and phosphorus (acid conditions)

of siliceous materials. Melts were, however, carried out with limestone–iron-ore additions as a means of comparison. The effect of temperature was investigated by allowing melts to cool between periods of oxygen blowing. Figure 3 shows that at low temperatures (metal allowed to fall below 1 300° C between blowing periods) phosphorus can be removed at silicon contents as high as 1% with soda ash, but only below 0·5% when using limestone–iron-ore. At high temperatures (rising to 1 500° C during individual blowing periods) phosphorus can only be removed by soda ash, and then only at silicon contents below about 0·5%. With limestone–iron-ore additions the lining attack at the high temperatures rapidly reduces the slag basicity and no dephosphorization occurs. Some small increase in the efficiency of silicon removal resulted with both additions, and soda ash gave useful desulphurization (average reduction in sulphur content of 0·025%).

Effect of slagmaking additions during the blowing of various phosphoric irons under basic conditions

All this work was carried out in the converter-shaped ladles lined with dolomite, on 110–150 lb

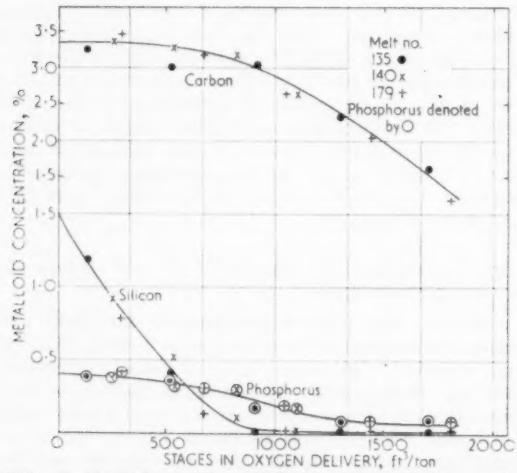


Fig. 4—Variation of metalloid concentration with oxygen tonnage rate, limestone–iron-ore mixture additions, single slag, 150–40 lb/ton, 130 lb metal, oxygen introduced at 10 ft³/min through $\frac{1}{16}$-in. lance

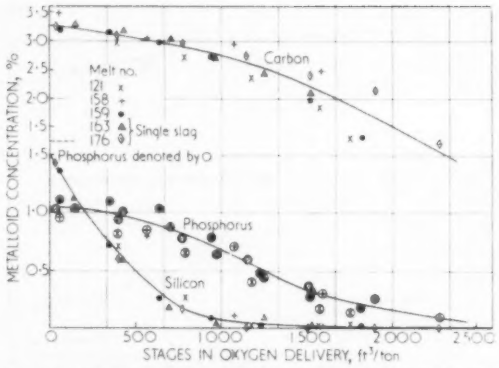


Fig. 5—Variation of metalloid concentration with oxygen tonnage rate, limestone–iron-ore mixture additions 175–44 lb/ton. All melts lanced except no. 121 ($\frac{1}{16}$-in. jet)

of iron and mostly with lances protected by cast coatings of magnesite–chrome cement (General Refractories Pyrocrete no. 3). Jetting tests were attempted, but generally proved less satisfactory on this small scale owing to the difficulty of judging the depth of the jetting probe in the slag and consequently its distance from the metal surface. Since then, in other work involving the ladle treatment of iron, a technique has been developed where the burn-off rate of lances and probes prepared in any particular way has been carefully measured over a number of heats so that a pre-set lance or jetting probe feed rate can be used to give fairly constant positioning of the point of oxygen emission. The use of water-cooled lances or probes on this scale is not attractive because of the order of the heat losses involved.

Both soda ash and limestone–iron-ore additions were investigated, but soda ash offered no advantage in silicon and phosphorus removal under basic conditions. The aim when using a basic-lined vessel

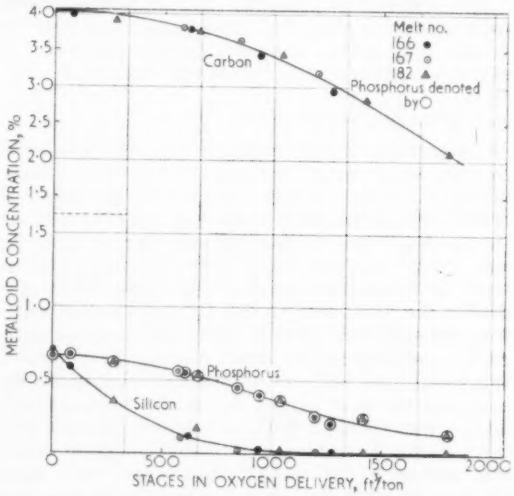


Fig. 6—Variation of metalloid concentration with oxygen tonnage rate, limestone–iron-ore mixture additions 131–31 lb/ton, oxygen through $\frac{1}{16}$-in. bore lance

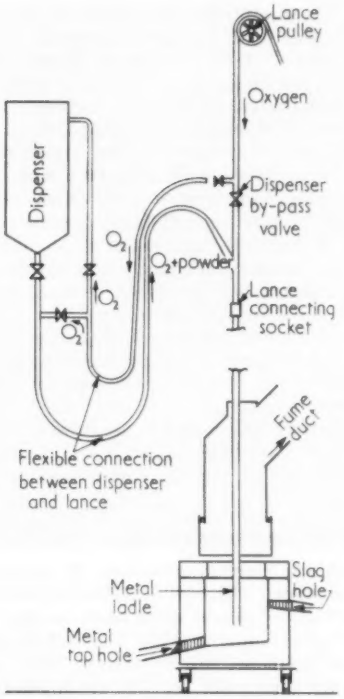


Fig. 7—Dispensing equipment

was, of course, early phosphorus removal with minimum decarburization. Using a wide range of irons it was found possible to obtain considerable dephosphorization during and immediately following silicon removal to give low phosphorus contents while maintaining the carbon content in the range 1·5–2·0%. Figure 4 gives the results obtained on a low-phosphorus iron typical of that obtained from Indian or similar ores using a single slag technique with additions of 150 lb/ton limestone and 40 lb/ton iron ore before starting the blow. Figure 5 shows results

TABLE I

Single slag treatment (powder dispensed: 5 parts lime, 5 parts millscale, 1 part fluorspar)

Initial metal weight, lb		111	
Cumulative oxygen delivery expressed as ft³/ton metal (based on initial weight)	0	605	1 209
Wt. of powder added in stages, lb	...	9·1	9·1
Cumulative delivery of constituents, lb/ton metal (based on initial weight)			
lime	...	83	167
millscale	...	83	167
fluorspar	...	17	33
Metal analysis, %			
C	3·57	2·86	1·72
Si	0·79	0·08	0·02
Mn	0·63	0·09	0·07
S	0·106	0·098	0·052
P	1·13	0·59	0·026
Slag analysis, %			
SiO_2	...	14·8	7·0
CaO	...	31·4	39·8
P_2O_5	...	12·8	14·3
Total Fe	...	21·1	23·7

Metal temperature rose in the range 1 425–1 550° C

TABLE II

Double slag treatment (powder dispensed: 5 parts lime, 5 parts millscale, 2 parts bauxite)

Initial metal weight, lb		113	
Cumulative oxygen delivery expressed as ft³/ton metal (based on initial weight)	0	315	1 189
Wt. of powder added in stages, lb	...	...	17·2
Cumulative delivery of constituents, lb/ton metal (based on initial weight)			
lime	...	...	142
millscale	...	...	142
bauxite	...	...	57
Metal analysis, %			
C	3·52	3·15	1·41
Si	0·90	0·27	0·03
Mn	0·65	0·23	0·04
S	0·111	0·099	0·059
P	1·35	1·30	0·10
Slag analysis, %			
SiO_2	...	30·3	6·0
CaO	...	15·0	34·2
P_2O_5	...	6·3	17·2
Total Fe	...	18·6	23·0

Metal temperature rose in the range 1 430–1 550° C

on a high-phosphorus high-silicon iron with total slag additions of 175 lb/ton limestone and 44 lb/ton iron ore. The individual values represent both multi-slag and single slag operation to the same total material addition as indicated in the key, there being no significant difference between the result of the two techniques. Figure 6 shows results on an intermediate-phosphorus low-silicon iron, with 131 lb/ton limestone and 31 lb/ton iron ore. All the heats were interrupted for sampling after slag removal with the slag additions made in stages before the start of the next blowing period.

It will be noted that in all cases there is appreciable phosphorus removal occuring during desiliconization and the phosphorus content is reduced to low levels with the retention of satisfactorily high carbon content.

(ii) Powder pretreatment process

The results obtained with normal surface additions of limestone/iron-ore in our small ladles could not be guaranteed to apply to full-scale plants where the specific oxygen input rates would be lower with less turbulence imparted to a melt as a whole, resulting in slower solution of the lime, reduced slag/metal contact, and possibly also an increased degree of stratification in the metal. In addition, the feeding of additions to the ladle surface on the full scale could be difficult. In any event, in spite of the experimental work published by ourselves and by Brymbo,[11] oxygen blowing with ladle additions appeared to remain unattractive to the majority of large-scale steelmakers. Occasional heats had been made during our early work with limestone and soda ash dispensed as powders with the oxygen yielding quite promising results and it was decided to investigate this sytem more fully with improved dispensing equipment. This work has been already reported by our colleague L. Cook.[12] The additions made, freshly burnt lime, millscale or iron ore and flux (bauxite or fluorspar), were ground to pass a 20 mesh sieve, the greater part of the powder being in the $-20+100$ mesh range. The general arrangement of the equipment used is shown in Fig. 7. As in the other ladle treatment

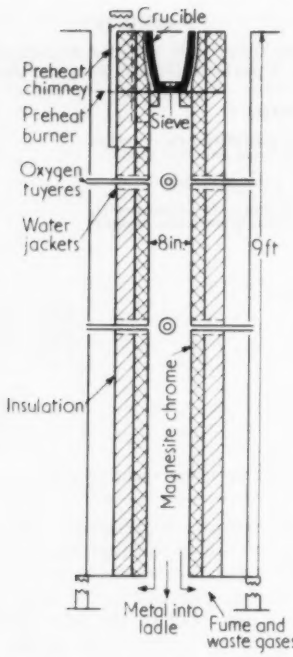


Fig. 8—General arrangement of co-current tower apparatus

work described the uncoated lance generally used was of $\frac{5}{16}$ in. bore, the oxygen being introduced at 10 ft^3/min. Early work in this particular field was carried out with $\frac{1}{2}$-in. bore lance on the assumption that there would be less tendency to blockage. It was found, however, that with the higher oxygen velocity in the smaller pipe dispensation was more satisfactory and, as is general in lancing practice, the lance consumption was more regular at a lower value. Some of the work was carried out with the tilting converter-shaped ladles as previously described, but with the amount of slag to be carried it was decided to use bottom-tapping ladles of somewhat larger diameter (11 in. as compared with 8 in.) for most of the experiments.

Substantial amounts of dephosphorization were achieved even in acid-lined vessels, but the powder consumption and ladle lining wear were in this case excessive. Under the more practicable basic-lined vessel conditions a single slag treatment was developed for irons of moderate phosphorus content, enabling low levels of residual phosphorus content to be obtained with ease. For irons of higher phosphorus content a double slag treatment was employed, which, with the incorporation of bauxite as a flux, enabled slags of saleable composition with regard to citric acid solubility to be produced.

Tables I and II represent the average results obtained over a number of melts for single slag treatment with fluorspar as a flux and for double slag treatment (initial slag arising from silicon removal taken off before dispensing began) using bauxite as a flux. The presence of considerable quantities of CaO and P_2O_5 in the average analysis of the initial slag in Table II is undoubtedly derived from the remelting of quantities of final slag adhering to the lining from previous blows. Where a newly lined vessel was used more typical figures were 0·6% and 0·1% for the CaO and P_2O_5 contents respectively.

These results show that in basic ladles, combined desiliconization, dephosphorization, and desulphurization can be achieved with a system which employs relatively simple equipment and which should give comparable results in full-scale operation. Where the mass of metal to be treated is so much greater and the heat losses consequently reduced the substitution of limestone for lime might be possible in many cases and would be attractive economically and from the point of view of grinding and storage. Although the tests reported used millscale, iron ore gives equally good results and would be the obvious choice for works operation.

An experimental powder dispenser of 4 tons capacity has been built and it is proposed to carry out trials on a pilot scale in a steelworks.

(iii) Tower pretreatment process

The idea of a continuous system in which iron was introduced down through a refractory-lined tower structure was developed quite early in our work and practical work began in 1955. A full report of the process as developed up to March, 1957 was given to a private conference for UK steelmakers held by the British Oxygen Company Ltd at Ashorne Hill, March, 1957. It is interesting to note that recently a paper was published by Gaines and Hilty of Union Carbide (Linde Company)[13] describing the early stages of their work on an almost identical process in the USA.

Our aim was to develop a system which would operate on a semi-continuous basis and not be subject to difficulties such as stratification of metal composition as encountered in ladle techniques and which would thus provide for more rapid and efficient reaction. A further important point was that by carrying out the reactions in free space whilst the metal was dropping down through the tower, refractory wear would be reduced to a minimum, since there would be practically no contact between the iron and the refractories. It was also hoped that by carrying out the reactions in a confined chamber where any carbon monoxide produced could be further burnt, the heat yield to the metal would be increased, particularly since there would be no contact with the refractories of the tower structure.

Figure 8 shows the present design of the tower as operated on a research scale. The refractory-lined steel-drum column is 9 ft high and 8 in. internal dia. The lining to the column consists of an outer layer of high-temperature insulation bricks and an inner working lining of magnesite–chrome concrete. Four water-cooled oxygen tuyeres, radially opposed, are located a little below the streaming crucible or tundish which is set in the top of the column. A further set of tuyeres is also provided lower down should they be required. The streaming crucible on this research scale consists of a plumbago crucible with a replaceable refractory sieve or distributor set in the bottom.

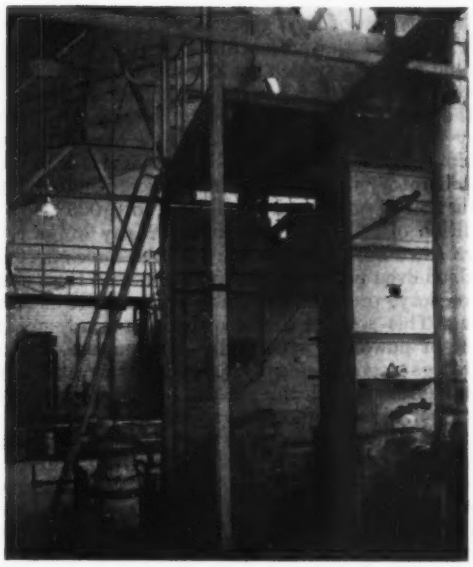


Fig. 9—Tower research installation at BORAD

This sieve has taken several forms, the most satisfactory for the present investigation being made by setting short sillimanite tubes in an aluminous cement disc. It has been shown that standard refractory strainers as used for iron and steel castings should be quite suitable for full-scale operation.

The working lining of the tower is preheated to about 1 100° C before operation by means of air–coal-gas burners, one located near the top streaming crucible firing tangentially and the other inserted in the bottom pointing upwards.

Figure 9 shows a general view of the equipment. The hoist for raising the ladle containing the untreated metal can be seen on the left, and a similar ladle to receive the treated metal is in position beneath the column. The square outer shell of the tower structure,

TABLE III

Silicon removal

No. of metal streams	: 2	
Dia. of metal streaming holes in sieve	: $\frac{1}{4}$ in.	
No. of tuyeres operating	: 4	
Metal pouring rate	: about 1 cwt/min	
Rate of oxygen introduction	: 1 100 ft³/h	
Equivalent oxygen used	: 402 ft³/ton	
Metal temperature at start	: 1 415° C	
,, ,, finish	: 1 480° C	
Metal analysis, %	*before*	*after*
C	3·67	3·57
Si	0·78	0·06
Mn	1·06	0·36
P	0·67	0·61
Iron in slag, %		22
Iron loss as fume		0·31
Efficiency of oxygen usage, %		78
Yield of iron, %		96

TABLE IV

Silicon and phosphorus removal (dispensed lime)

No. of metal streams	: 8	
Dia. of metal streaming holes in sieve	: $\frac{1}{4}$ in.	
No. of tuyeres operating	: 4	
Metal pouring rate	: about $\frac{1}{2}$ cwt/min	
Rate of oxygen introduction	: 2 000 ft³/h	
Equivalent oxygen used	: 1 465 ft³/ton	
Equivalent lime addition	: 66 lb/ton	
Metal temperature at start	: 1 400° C	
,, ,, ,, finish	: 1 470° C	
Metal analysis, %	*before*	*after*
C	3·34	1·45
Si	0·58	0·01
Mn	0·78	0·02
P	1·20	0·16
S	0·081	0·059
Slag analysis, %		
Fe		19·9
P_2O_5		17·9
Efficiency of oxygen usage, %		87
Yield of iron, %		86

which was available from other plant, merely supports the internal circular column and is not a necessary aspect of the design.

The initial experiments in the tower were restricted to straightforward desiliconization, but it has been shown more recently that lime may be introduced to the system to achieve full pretreatment to include phosphorus removal. The lime addition has been made in two main ways, either adding as lump to the receiving ladle catching the iron beneath the tower, or, more satisfactorily, by dispensing the lime into the reaction column as a powder through the tuyeres with the oxygen, which appears to give the best results.

The details given in Tables III and IV are taken from two typical pours, the first with the tower being used for silicon removal alone, and the second with lime introduced by dispensation through the oxygen tuyeres for phosphorus removal.

Our small-scale experiments have shown that the most efficient operation can only be achieved if the iron being poured is above 1 350° C. Lower values may, however, be acceptable on a larger scale since heat losses from the system will be very much reduced.

Up to $\frac{1}{4}$ in. dia. the size of the holes in the streaming sieve does not seem to affect greatly the desiliconization efficiency and the number and size of holes may be regulated as desired to control the metal streaming rate. With larger holes, however, the size of droplet formed has been shown to increase significantly, with reduced reaction during the period of fall. The metal yield values and the iron content of the slags formed compare favourably with lancing in the ladle for the same results on a similar weight of metal.

From work now proceeding under our colleague T. C. Churcher we feel that this process should achieve industrial application. The reactants are brought into intimate contact over a large moving surface area, so that reaction is very rapid and relatively unhindered by any concentration gradients in the metal phase, and as compared to other methods of continuous treatment, such as special launders, it offers the advantage

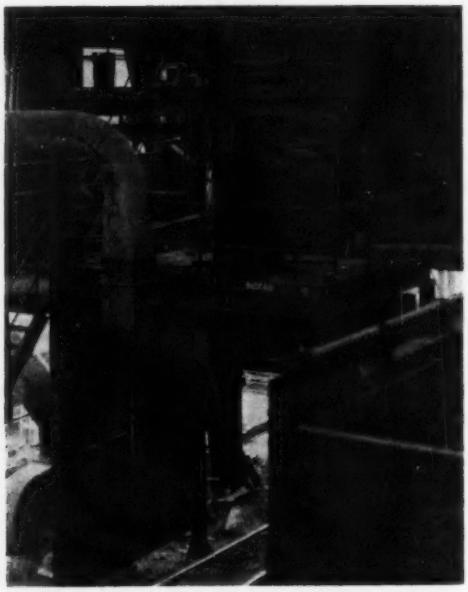


Fig. 10—Tower pilot installation at Consett

of minimum refractory/metal contact and thereby reduced refractory wear. The main difficulty which is likely to occur on the full scale is in the provision of sufficiently robust and easily replaceable sieve discs in the streaming crucible or ladle. This and other full-scale practical problems are being investigated on a pilot scale with equipment installed at The Consett Iron Co. Ltd, whose co-operation in this venture we gratefully acknowledge. Figure 10 shows the pilot installation.

Our research equipment is normally operating at a rate equivalent to 3 tons/h of metal treated, on occasions increased to 10 tons/h. The pilot plant at Consett is capable of extending this to a rate of 60 tons/h, using, in the first place, 20-ton batches of metal.

TREATMENT OF FOUNDRY IRON

(i) Desulphurization

For several years it has been apparent that there was a widespread need in the ironfounding industry for a ladle desulphurizing method that could be applied to metal immediately before casting into moulds. Methods involving blowing powdered desulphurants below the metal surface were widely publicized in the overseas technical press, but no equipment for the purpose was available in the UK. Work at BORAD, mainly under the direction of Dr Harding, during this period was aimed at (*a*) examining the conditions necessary for success of the treatment, and (*b*) developing suitable equipment. It was found that good results could be obtained with calcium carbide, calcium cyanamide, or burnt lime, the two former being the most effective. It was desirable to use a metal temperature above 1 350° C, preferably above 1 400° C, and to blow the powder well into the body of the melt in a steady and not too violent stream of inert gas. It was also found necessary to avoid the presence of considerable amounts of fluid acid slag, which could cause sulphur reversion from the sulphur-rich dry slag. The particle size of the powders did not appear to be critical, provided they were in the range that could be handled by the equipment and not so fine as to deteriorate too rapidly. In laboratory melts of 150 lb a typical result was the reduction of sulphur from 0·10% to 0·025% by an addition of 2% calcium carbide. Many works trials have since been carried out, and the bulk effect has enabled even better results to be obtained than in the laboratory, provided adequate temperature is available. This work indicated also the most suitable form of powder dispenser for the purpose, i.e. one which gave good control of powder flow rate over a suitable range, with the powder thoroughly dispersed in a gas stream of moderate volume. A dispenser on these lines was developed and will shortly be available to industry. Figure 11 shows this dispenser being used for ladle desulphurization. The principles established for foundry iron are expected to find some applications also for desulphurizing molten pig iron and steel. In the latter case, the use of lime powder is necessary rather than calcium carbide if an increase in carbon content is to be avoided.

(ii) Increasing the carbon content of foundry melts

Such a process is attractive to ironfounders as it enables them to melt increased proportions of cast iron and steel scrap of lower quality. Work at BORAD has shown that similar equipment is needed as for desulphurizing, and that a carbon increase can be obtained with practically any form of carbon powder. The best results are given by graphite of high purity (say, 99%C), which may be used alone

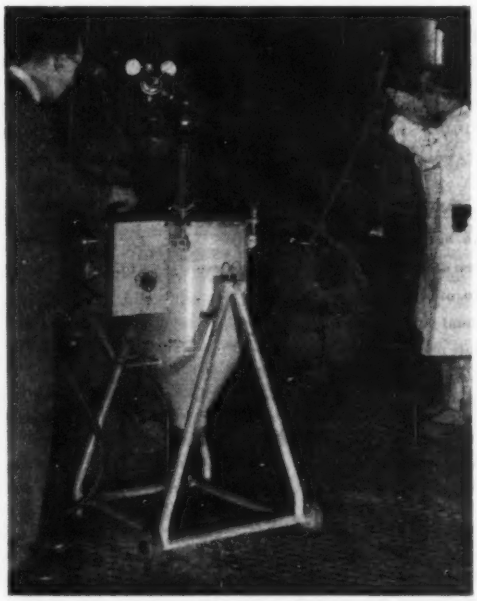


Fig. 11—Dispensation of calcium carbide in ladle desulphurization

or with desulphurants or other additions. Again a temperature above 1 350° C is preferable, also dispersion of the powder in an adequate bulk of metal. With carbon contents below saturation, carbon recoveries of 50–90% are obtained, depending on the conditions obtaining. In this case also it is possible that applications for injecting carbon may also occur in pretreatment or steel manufacture.

(iii) Oxygen lancing in the cupola hearth

Oxygen enrichment of the air blast to cupolas has been practised for some time, generally under special circumstances where the fuel available is of too low a grade to give satisfactory melting using air alone or under more normal conditions where enhanced metal temperature and melting rate are required. Recently, however, an entirely different approach to the use of oxygen in cupolas has been made in our research foundry.

Whilst considering the feasibility of carrying out oxygen lancing operation in the hearth of blast-furnaces for the desiliconization of iron it was recognized that under the conditions existing in both blast-furnaces and cupolas, where a coke column persists to the hearth, the increase in metal temperature achieved could increase the carbon content of the iron to its saturation value for the higher temperature. On surveying the literature it was found that certain Russian investigators[14] had lanced oxygen into the iron contained in the well of a cupola, and claimed that for each 100° C rise in metal temperature the carbon content of the iron was increased by about 0·25%. The rise in metal temperature was achieved mainly as a result of silicon oxidation from the iron. The carbon contents both before and after lancing were all representative of saturation values for the iron temperatures achieved.

It was realized that this process might make possible the carburization of non-equilibrium low-carbon irons melted in a cupola from high-scrap or all-scrap charges. The effect of rapidly raising the temperature of the iron, the flushing and cleansing action on the submerged coke-removing slag, and the general stirring action produced might be expected to make possible the attainment of equilibrium or near-equilibrium carbon contents at the same time as increased iron temperature.

The practical investigation of the process has been carried out using a small cupolette, 18-in. shaft dia., 50 in. height from hearth to charging sill and normally operated with a coke bed height 21 in. from the tuyere level. An inclined port was provided in the wall of the cupolette just below the wind belt to allow a lance to be inserted down into the iron collected on the hearth. A sketch of the installation is shown in Fig. 12. Oxygen was introduced at various rates and for varying times through a $\frac{5}{16}$-in. bore uncoated mild-steel lance.

Originally the cupolette was used solely as a melting unit to provide molten iron for subsequent oxygen lancing experiments in the ladle, and no detailed study of its operation had been carried out. Since operation had always been on an intermittent basis using considerably larger pig than is desirable for a unit of this size, the coke/metal ratio and the bed

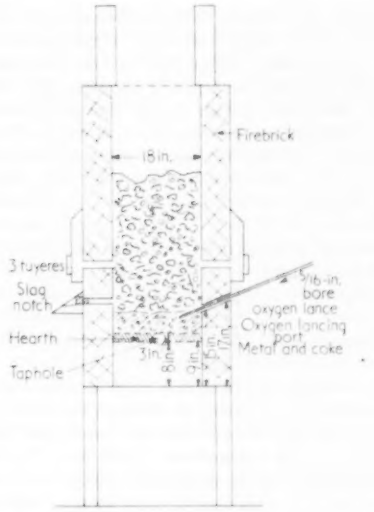


Fig. 12—Cupolette employed for lancing experiments

height employed were abnormally high by generally recognized standards. Under these conditions attempts to produce low-carbon melts from mixed scrap and pig charges were not successful. The steel scrap used was small and, quite independent of the amount of scrap charged, carbon contents approximating to equilibrium values for the tap temperature were obtained. When these melts were lanced in the cupolette, however, we were able to obtain a small increase in carbon content proportionate to the rise in metal temperature obtained by silicon oxidation as in the Russian work.

We did not consider, however, that these results were of any practical value. The rise in carbon content was too small and the increased metal temperature (100° C for the injection of oxygen to the extent of 200 ft³/ton of metal) did not appear competitive economically with blast enrichment, in view of the silicon loss and the lance consumption.

Alterations were then made to the method of cupolette operation using all-steel scrap charges (with lump FeSi) and reducing the bed height above the tuyeres by 3 in. to give a coke/metal ratio of 1 : 6. The choice of this condition achieved the desired result and an iron containing 2·4%C and 1·0%Si was readily obtained, which, when lanced with oxygen to the extent of 340 ft³/ton, gave a final carbon content of 3·0%C and a temperature rise from 1 330° to 1 435° C.

The remaining unattractive feature of the process seemed to be the silicon loss involved, although the results quoted above were sufficiently good to suggest that under certain conditions the cheapening of charges to include higher proportions of scrap and the increased metal temperature obtained might be attractive.

It had been noted, however, that the efficiency of oxygen usage based on the silicon removal obtained was generally lower than when lancing in the ladle and the temperature increase obtained was higher

than would be expected from the amount of silicon removed. This suggested that a proportion of the oxygen was being consumed in the combustion of bulk coke existing just above or beneath the metal surface. For this reason it was decided to omit any silicon addition in the cupola and melt down steel scrap alone. Under the same melting conditions as gave a normal carbon content of 2·4% the metal lanced on the hearth rose to 3·15% carbon at a temperature of 1 395° C. This iron–carbon alloy could then be tapped into the ladle and suitable ferro-alloy addition made to produce an acceptable foundry iron composition. Throughout this work no deleterious effect on metal yield has been noted. In fact the oxygen-lanced heats tapped easily and cleanly. No abnormal lining wear has resulted. It thus appears possible to produce high-temperature high-carbon melts from all-scrap charges by lancing in the hearth of the cupola, without hot blast, and the maximum silicon and manganese yield may be obtained by withholding these additions until after tapping. Further work is proceeding and results will be published in more detail later.

As stated in the introduction it has been the object in this paper to solve some of the problems associated with, and to develop, the use of industrial gases in the treatment of molten iron. There remains, however, much that still needs to be done and active research continues within BORAD.

ACKNOWLEDGMENTS

The authors wish to thank the directors of the British Oxygen Research and Development Ltd, for their permission to publish this paper. They also thank the following organizations for permission to reproduce the figures indicated: Butterworths Scientific Publications Ltd (Fig. 1), *Iron and Coal Trades Review* (Figs. 3, 7), The Consett Iron Co. Ltd (Fig. 10).

REFERENCES

1. E. A. Wheaton: *AIME Proc. O H Comm.*, 1940, vol. 23, pp. 151–154.
2. S. F. Elam: *Ibid.*, 1949, vol. 32, pp. 87–92.
3. A. Jackson: *JISI*, 1949, vol. 162, p. 144.
4. D. F. Marshall: *JISI*, 1952, vol. 172, pp. 318, 319.
5. W. J. B. Chater: *Chem. Eng. Sci. Spec. Supp.*, 1954, vol. 3, pp. 105–117.
6. J. A. Charles: *Research*, 1958, vol. 11, pp. 102–107.
7. J. A. Charles, W. J. B. Chater, and J. L. Harrison: "Oxygen in Iron and Steel Making": 1956, London, Butterworth.
8. P. J. Gledhill, P. J. Carnal, and K. H. Sargent: *JISI*, 1957, vol. 186, pp. 198–211.
9. K. H. Sargent: *Iron Coal Trades Rev.*, 1959, vol. 178, pp. 79–85.
10. J. A. Charles and T. C. Churcher: *Ibid.*, 1957, vol. 174, pp. 667–672.
11. E. Davies: *Ibid.*, 1956, vol. 172, pp. 987–988.
12. L. Cook: *Ibid.*, 1958, vol. 177, pp. 87–93.
13. J. M. Gaines and D. C. Hilty: *J. Met.*, 1958, vol. 10, pp. 452–455.
14. N. A. Voronova and O. A. Trigub: *Lit. Proiz.*, 1955, no. 7, pp. 17–20.

Practical aspects of pretreatment processes

By J. L. Harrison, F.I.M.

SYNOPSIS

Chemically it is of little consequence whether metalloids are removed in the steelmaking furnace or partly by ancillary processes. On economic grounds it may be desirable to carry out pretreatment of the iron.

Metalloid content and increased quantities of iron may have an effect on open-hearth furnace output, fuel consumption, and refractories, increasing the operating cost. Although the O H furnace has greater flexibility than other steelmaking methods, high metallurgical loads may give an unfavourable comparison with newer processes. Low capital pretreatment processes may improve the situation.

Various pretreatment methods are described and a cost summary is given. 1694

IRON PRODUCED by the blast-furnace contains between 5·5% and 8·0% impurities which must be reduced to about 0·5% by a refining process. The impurities are carbon, silicon, phosphorus, manganese, and sulphur with occasionally vanadium, titanium, and other elements. Chemically there are a number of ways in which they may be separated from the iron, but reacting the impurities with oxygen offers the most practical method. The oxygen used may be in the combined or free state, the choice of which influences the economic result. The vessel in which the reactions are carried out does not fundamentally affect the chemical reactions since these are dependent on the basic laws of thermodynamics, but it does have an important bearing on the economics of the manufacture of steel.

Manuscript received on 12th February, 1959.
The author is with British Oxygen Gases Ltd.

For almost 100 years the open-hearth process has been the major method by which steel has been produced and, in spite of the introduction of several new processes, it remains pre-eminent in the steelmaking field. The new processes have so far only satisfied part of the increasing demand for steel. Although they will continue to expand as steel demand increases and may ultimately replace some of the O H steelmaking capacity, it is unlikely that the quantity of steel made by the latter will diminish at a very rapid rate.

Many millions of capital has been invested in O H plants which must show a return to the investors before they can be replaced. That they will be replaced by other processes is, at this stage of steelmaking development, largely conjectural. One of the main reasons is that the O H furnace has a greater degree of flexibility than all of the other processes. It can work with almost any ratio of pig iron to scrap in the charge and changes can be made fairly readily to meet changing economic conditions in the raw-material market.

Refining of iron into steel in the O H process is mainly carried out in the furnace by the direct and indirect oxidation of the metalloids with the production of either solid or gaseous oxides. The solid oxides combine with a base to form a stable constituent of the slag and the gaseous products leave the system through the slag surface.

It is not essential that the reactions should all be carried out in the furnace and indeed it may not always be desirable. The O H furnace is an expensive piece of capital plant and is dependent to some extent on the throughput to make it economically operable. The effect of throughput is becoming more important in view of the somewhat lower investment costs and higher output figures of some of the new processes. If, therefore, methods can be devised which enable some of the refining to be effected away from the O H furnace in plant of low capital cost and give an overall gain in production rate, there is offered the possibility of an increased return on capital investment and lower total steelmaking cost.

Despite the ability of the O H furnace to operate in the UK most economically on high scrap charges, it is not possible always to do so. In times of high demand for steel there is a shortage of steel scrap, which forces the steelmaker to use an increased percentage of pig iron. A higher ratio of molten metal introduces a greater quantity of sensible and potential heat into the system and also reduces the proportion of cold material to be melted. Therefore it should have the effect of increasing the production rate. Under certain conditions this is true, as may be observed from the information given by the productivity team which visited the USA in 1952. The point is clearly made by Marshall[1] who compared the effect of increased pig iron ratios in furnaces in the USA, Germany, and the UK using respectively low, medium, and high phosphorus iron. The US figures, using iron containing 1·00%Si, 0·30%P, 0·70%Mn, showed an increase from 17 to 20·5 tons/h by raising the proportion of hot metal from 20% to 55%. In Germany, however, using iron containing 0·50%Si, 0·60%P, 2·50% Mn, the output rose by 10·8–11·15 tons/h when the hot metal was increased from 20% to 35% but it fell to 10·0 tons/h if the proportion was raised to 55%. Similarly, in the UK the output rose by 13·7% by increasing the proportion from 27% to 37% of mixer metal containing 0·40%Si, 1·20%P, 0·60%Mn. If, however, only 30% of direct metal was employed containing 1·00% Si, 1·40%P, and 1·50%Mn, there was a decrease in output of 5·1%. It is clear, therefore, that if the iron contains a small quantity of metalloids, a gain in production rate is possible by increasing the hot metal proportion. If, however, the metal has a high metalloid content, the effect is reversed and a decrease in production rate results.

Confirmation of the first effect is evident from the published results of Cook[2] who showed that using iron containing 0·80%Si and 0·30%P, and increase of hot metal from 56–60% to 76–80%, gave an extra 2·0 tons/h output equivalent to 13·0% at the Volta Redonda Works in Brazil.

The adverse effect of high metallurgical load has been shown by Jackson[3] who stated that the effect of changing from mixer metal to direct metal reduced output by 25%. The output of a tilting O H furnace had decreased from 3 000 tons/week to 2 500 tons/week using inferior iron and to 1 700 tons/week using direct metal. If American-type iron was available such furnaces could make 4 000 tons/week.

Marshall[1] quoted figures for a shop using 25% pig iron and indicated that a reduction in phosphorus from 1·06% to 0·27% gave an increase of 10% in output. He also showed the effect by means of a statistical analysis of O H operation over 5 weeks. The correlation co-efficient for the variables P and Si were —0·588 and — 0·512 respectively and were regarded as very significant.

The effect of higher metallurgical load is cumulative. Not only has a greater weight of elements to be oxidized, but this in turn also increases the quantity of bases and oxides required in the slag to combine with them. The resultant increase in slag volume decreases the rate of heat transfer from the flame to the metal with effect on the production rate, fuel consumption, and refractory life.

Gibson[4] showed that in cold metal practice a change from 1·48%P to 0·40%P in a 1%Si iron reduced the slag bulk from 9% to 5·1% when using 30% pig iron charges and from 18% to 10·2% when using 60% pig iron. With the latter percentage, the lime would be reduced from 1·62 to 0·90 cwt/ton of ingots.

Marshall[1] pointed out that in comparison with the USA, UK plants have to remove six to eight times the quantity of phosphorus from iron of greater sulphur content using oil significantly higher in sulphur. The effect is an increase in slag bulk from the range 8–12% in the USA to a 15–25% range in the UK.

A number of authors, including Wheaton[5] and Elam,[6] have shown the effect on productivity by reducing silicon alone from the range 1·10–1·25% to 0·75–0·80%. The gains ranged between 10·8 and 16·4% as measured in tons/h. This is in good agreement with Jackson.

From the brief summary, the following may be concluded:

(i) Increasing the proportion of hot metal in the charge of an O H furnace does not necessarily decrease the production rate

(ii) If the hot metal has a high content of metalloids, particularly Si and P, an increase in the proportion used in the charge will decrease the production rate

(iii) A decrease in the production rate has an adverse effect on production costs

(iv) To offset the reduction in output and the consequent additional cost, methods of pretreating the iron, which embody low capital costs are desirable.

In addition any method of steelmaking which incorporates a pretreatment process must not result in a final yield of iron which is too low to make the process economical.

It is also evident that pretreatment processes are desirable which are capable of reducing both Si and P from the iron, since both are responsible for prolonged refining operations.

The reduction of silicon in iron has been practised for some time using gaseous oxygen as the means of oxidation. It has become standard at a number of works. The reduction of phosphorus has not developed quite so far, but several methods have been developed using special types of furnaces, or modified transfer ladles. These all use oxygen. The next section of the paper will describe in brief the various established methods.

Over the past few years work has been progressing under laboratory and pilot conditions to develop methods of desiliconizing and dephosphorizing which may be more efficient technically and show greater economies in operation. These have been described in a paper by Chater and Charles[7] and will not be discussed here.

PRETREATMENT PROCESS

Although in the more accepted sense not pretreatment processes, methods of removing Si and P from iron whilst retaining most or some of the carbon have been practised for many years.

For instance the almost extinct puddling process effectively removed silicon and phosphorus by oxidation with iron oxide. It was essentially a low-temperature process. The carbon remained at around 1·0% at this stage and even at 2·0%C, 75% of the phosphorus had been eliminated.

In 1877 Sir Lowthian Bell[8] devised a process known as pig washing in which iron was rotated in a furnace with iron oxide. It was developed by Krupp and later at the Brier Hill Steel Company in the USA. It was capable of reducing phosphorus down to 0·10% under UK conditions and from 3·0% to 0·65% in Germany. The 0·10%P iron in USA was reduced to 0·01%P and eventually to 0·006%P. The furnace was like a cement pan mill and had a lining of hematite which was water cooled. Twelve tons of iron were treated in 15 min. The yield was equal to the amount of iron used because of the reduction of the added ore. The slag containing about 50%FeO and 17%Fe_2O_3 was returned to the blast furnace. Unfortunately, such a method would be unsuitable for present-day requirements since the final temperature of 1 250° C was only 50–100° C above the iron melting point. It does, however, indicate that such processes have been known for over 80 years.

When a dephosphorizing process is carried out at higher temperatures, such as will follow a desiliconizing operation, lime is essential to combine with the phosphorus pentoxide. Lime is also desirable as a flux even if the process is purely desiliconizing. It is not essential, but it has the effect of reducing the iron oxide content of the slag and slightly improving the metallic yield. If, however, the metal contains vanadium, no lime is added since the V_2O_5 is required to combine with iron oxide from which it can be recovered in a later process. Thus, in spite of the lower yield, the process may be economical because of the valuable by-product.

In most of the processes described later it will be seen that lime is used. Iron oxide may also be introduced as a coolant and to increase the metallic yield or to provide iron oxide to the slag to assist metallurgical reactions. Cooling additions of scrap may be made to preserve the reacting-vessel life and give some thermal economy.

In the next section various pretreatment processes are described. They are not placed in order of merit, but in their sequence in the steelmaking operation.

Blast-furnace runner pretreatment

The main advantage attending the success of a process of pretreatment in the blast-furnace runner would be that it could be conducted without introducing a separate batch operation. The capital investment cost would be expected to be low.

Desiliconizing experiments on these lines have been in progress at the Moyeuvre Works of Wendel et Cie, France, in conjunction with IRSID for some time.[9] The iron available from the blast furnace contains 0·30–1·60%Si, but high-silicon iron results in uneconomic conversion in the Thomas converters because of slopping. In the experimental plant, part of the blast-furnace runner has been replaced by a channel in which are built a series of porous refractory blocks. The total length is about 18 ft. The channel is above a pit containing the oxygen distribution equipment. Before the channel are two hoppers which introduce lime and scale to the molten metal. To mix the fluxes and metal, the stream is made to fall about 2 ft before it enters the channel. About 30 tons of metal are treated in 5–6 min. Scale is added at the rate of 24 lb/ton and lime at 8 lb/ton. Oxygen is blown through the porous bricks at the rate of 280 ft³/min and is consumed at the rate of 60 ft³/ton. The silicon is reduced from 0·70–0·80% to 0·45–0·50%. The temperature gain is 40–65° C if allowance is made for the normal 15° C drop in the runner. The slag contains 5–6%Fe and is less basic than the usual desiliconizing slags. The iron loss is 1·0–1·5%. The process is characterized by an almost complete absence of fume. It does not interrupt the flow of metal to the steel plant and it has a high metallurgical efficiency and a low oxygen consumption. It is not known, however, what the results would be on higher silicon iron. The cost of the replacement of the porous blocks may be high and the life of the runner may be insufficient to treat batches of metal of 50–75 tons over long periods. There is need for more work to be done in this particular field.

Ladle pretreatment

In certain European countries the practice of pretreating iron either in the transfer ladles between the blast-furnace and the melting shop or after storage in a mixer has become established. Generally speaking, European ores are associated with a highly siliceous gangue which results in an iron containing undesirable quantities of silicon. In the UK, iron produced from home ores or mixed burdens may contain 1·0%Si or more, although the use of sinter in the blast-furnace is improving the position. In Western European countries the ores in the Minette field produce an iron which is often too high in silicon for conversion in Thomas plants without excessive splatter and consequent low ingot yield. Iron containing over 0·50%Si is undesirable. Several works, particularly in Germany, are concerned with V- and Cr-bearing ores and consequently have introduced pretreatment processes to remove these elements. Work on desiliconizing has also been reported from the USSR.

The extension of pretreatment to achieve the removal of phosphorus has not yet become an established industrial process. Much work has been done on laboratory and pilot-plant scales. The work of Mr E. Davies of the Brymbo Steelworks Ltd[10] has been reported using suitable slag mixtures added to iron in a basic ladle after the removal of the desiliconizing slag.

The paper by Chater and Charles (*see* pp. 319–328, this issue) records results obtained on small-scale desiliconizing and dephosphorizing experiments in which the slag constituents were introduced by means of an oxygen stream below the metal surface. It is expected that before long such processes will become established industrially in OH melting shops.

Desiliconizing in transfer ladles between the blast furnace and the melting shop is now established in three UK steelworks.[10–13] The practice is ideal for works having high-silicon iron and inactive mixers and may be quite economical in conjunction with active mixer operation.

Usually the desiliconizing is conducted in firebrick-lined ladles, the capacities ranging from 18 to 60 tons. Limestone is added to form a monobasic slag and millscale or fluorspar additions may be made. The quantity of limestone is dependent on the silicon content of the iron and the quantity to be removed, but is about 0·5–1 cwt/ton of iron treated. About a third of the quantity is added to the bottom of the ladle and the remainder during pouring, or all of it may be added to the metal surface.

Oxygen is introduced through $\frac{3}{4}$-in dia. bare steel lances at a pressure of 120–180 lb/in^2 and a flow rate of 10–15 ft^3/min/ton. The process takes about 20 min. It is accompanied by a substantial increase in temperature. The removal of 0·70%Si with oxygen gives a theoretical temperature rise of 217° C which in practice may not be much lower as the removal of silicon is accompanied by the oxidation of other elements. Additions of pit scrap or ingot moulds, amounting to about 20–25% of the initial weight, are often made to counter the temperature rise, the final increment being 100–150° C. Oxygen efficiency is quite high. The Brymbo results[11] showed an average of 82·5% for Si and Mn removal assuming that 52·5 ft^3 O_2/ton of iron was available from limestone and soda ash.

The higher metal temperature does not appear to have a serious effect on ladle life. Under normal conditions it is frequently shortened by skull formation. As this is entirely eliminated a decrease in ladle life of 20% maximum is experienced. In one steelworks no reduction in life has been found when using a good quality jointing cement between the ladle tiles.

The use of consumable lances is the usual practice in the UK, but in Germany water-cooled lances have been used immersed below the surface to a depth of 12–20 in.[14] The copper lance lasts about 1 000 heats or 35 000 tons of iron treated. No mishaps have occurred due to explosions.

The use of a basic slag is standard in the UK largely because of the improved metallic yield obtainable. In the plant at Oberhausen, Germany,[14] no limestone additions are made since vanadium recovery is required. Vanadium oxidizes and passes into the slag giving a V_2O_5 content of 5·35% equivalent to 3·0%V. The slag contains about 24%SiO_2, 23%MnO, and 24% Fe including shot. After removal of V the slag is returned to the blast-furnaces for Fe and Mn recovery. The iron losses are reported as being 18 lb/ton (0·82%) to the slag and 13 lb/ton (0·135%) as dust, making a total of 0·95%.

The removal of Cr is also practised in Germany as part of a pretreatment operation.[15] Using 35% Conakry ore in the blast-furnace burden, a pig iron containing 0·80%Cr results. The maximum required in the iron is 0·10–0·12%Cr. Batches of 30–40 tons have been treated in 42-ton capacity ladles. Oxygen was blown by means of water-cooled immersed lances at a depth of 12–20 in. having two nozzles at 180° to each other. The oxygen consumption showed 96% efficiency and was used at the rate of 175–350 ft^3/min. To achieve Cr removal it was necessary to keep the temperature low. To do this and to assist Cr removal, millscale was added at the rate of 66–132 lb/ton depending on the Si content. The process was accompanied by a temperature fall of 0–30° C. The scale addition influences the yield, which is 96–98%, in spite of 187 lb/ton of slag (8·5%) containing 30–40%Fe.

The use of a batch process employing a separate desiliconizing station is not always practicable owing to shop layout and transport problems. To overcome these difficulties, an interesting piece of equipment has been built at the Maximilliansshutte in Sulzbach-Rosenberg, Germany.[16] The plant has been designed to desiliconize iron in quantities of 12 tons as it leaves the inactive mixer before blowing in a Thomas converter. The chamotte-lined ladle stands on a weighing machine under a fume hood. Two water-cooled probes project through the hood and are lowered to within a few inches of the ladle bottom. During filling the probes are gradually raised and a distance of about 8 in. maintained from the metal surface. Speed of pouring and lance elevation are controlled from the ladle weight. No limestone is added and the Si is lowered in 2–3 min from 0·30–0·40% to 0·10–0·20%. The probes deliver oxygen at a pressure of 44–88 lb/in^2 through 0·945-in. nozzles. The oxygen

TABLE I
Final silicon content of iron desiliconized with oxygen in an active mixer

Range of Si content, %	No. of results	Percentage of total results
0·61–0·70	2	13·3
0·51–0·60	1	6·7
0·41–0·50	6	40·0
0·31–0·40	4	26·6
0·21–0·30	1	6·7
0·11–0·20	1	6·7
Total	15	100·0

consumption is 100–140 ft³/ton. In view of the low initial silicon the oxygen efficiency of 45–60% for Si removal is considered good. There is no reason why such a method should not be practised on a larger scale even if pouring were interrupted for short periods to prolong injection and remove more Si. It would probably overcome difficulties in siting desiliconizing stations in some works.

The use of oxygen–steam mixtures in ladle desiliconizing

The most undesirable feature of a pretreatment process using oxygen is the evolution of brown fumes of iron oxide. It is not proposed to enter the controversy of the mechanism of its formation. Measurement of the fume emitted has shown that the major proportion of the dust is iron oxide having a grain size less than 0·5μ and a high optical density. Several methods are available of collecting and disposing of the fume which make the final effluent acceptable to local authorities. The problem has been approached also from the angle of the prevention of fume formation at the source.

Certain investigators have formed the opinion that by cooling the hot spot at the point of contact between the oxygen stream and the molten metal the problem can be minimized. Whether this is a real or apparent effect has been debated on several occasions without reaching finality. The effect on the appearance of the fume is, however, very noticeable when a proportion of steam is introduced with the oxygen. This can be observed from the excellent film available at Messrs Dorman Long (Steel) Ltd which shows the result of varying the oxygen–steam ratio in ladle desiliconizing practice. Using a 50 : 50 mixture by volume, the observable fume is appreciably reduced and hardly apparent using a 63 : 37 steam–oxygen mixture (about 50 : 50 by weight).

Results using an oxygen–steam mixture through a water-cooled nozzle positioned about 4–6 in. above the metal surface, have been reported.[18] The tests were carried out at the Steel Company of Wales Ltd in a 70 tons capacity ladle containing 35–40 tons of iron. Millscale and lime were added in various proportions. The oxygen jet was operated at 90–95 lb/in² and the oxygen flow rate was 20 000 to 25 000 ft³/h. No details of the steam quantity were recorded, but the mixture was effected in a Kraus atomizer attached to the jet. The operation took 25–30 min and the dense brown fume was replaced by a pinkish fume of much less density.

The following composition changes were noted:

	C	Si	S	P
Before jetting	4·19	0·50	0·032	0·51
After jetting	3·77	0·04	0·026	0·28
Reduction	0·42	0·44	0·008	0·23

It will be observed that an appreciable quantity of phosphorus was removed.

Work in the USSR has been recorded[19] in which a lance was used both for surface blowing and to inject oxygen–steam mixtures 6–8 in. below the surface of 55–65 tons of iron in a ladle. The steam content was 20–40% by weight. The steam and oxygen pressures were 4–6 atm and 2·5 kg/ton (2 540 lb/ton) of steam and 4–7 m³/ton (140–247 ft³/ton) of oxygen were consumed. Ore and limestone were used separately or mixed together and added to the stream entering the ladle. The initial Si range 0·48–0·75% was reduced to 0·06–0·28%. The lower figure was obtained by injecting oxygen and steam after adding iron ore to the metal stream. Minimum Si reduction occurred when no ladle additions were made. Phosphorus was not affected. The iron temperature increased between 25° and 62° C during blowing. No brown fumes were observed when using mixtures containing 20–40% of steam by weight. The use of ladle additions reduced the quantity of steam necessary. When surface blowing, the oxygen–steam mixture was injected at a pressure of 7·5–10·5 atm compared with 4·5–7·5 atm during submerged lancing. Also, the consumption of the oxygen–steam mixture was 25% lower per ton and per unit of time, and a higher final temperature was achieved as only 25% of steam in the mixture was effective in eliminating fume. These results are more optimistic than those recorded of work in the UK.

It would seem that the use of steam is effective in reducing the appearance of brown fume if not eliminating it. There is not the same temperature increment as with oxygen used alone which is one of the valuable features of the process, since physically hotter iron will in itself reduce the refining time in O H practice.

The techniques of pretreatment in transfer ladles are quite simple whether consumable lances or water-cooled probes are used. Difficult problems arise, however, in introducing the practice in steelworks. The iron requirements in a modern works may range from 500 000 to 750 000 tons per year. These quantities pose handling problems without the introduction of an intermediate operation in the blast-furnace and melting shop. If a new works is under consideration, provision of a separate pretreatment building can be incorporated and the movement of traffic organized to suit the layout. In an older works, adaptation of an existing site has to be done and this is often chosen near the mixer where handling facilities already exist.

The pretreatment of 750 000 tons of iron per year means that about 2 100 tons must be treated in 24 h, i.e. 90 tons/h. On the basis of tapping the blast-furnace every 4 h, six 60-ton capacity ladles require handling. The minimum time available to pretreat

TABLE II

Result of oxygen–steam blow for desiliconizing in an active mixer

Blow no.	Lance positions	Duration of blow, min	Oxygen		Steam		Steam, %		Metal composition, %		
			Vol, ft³	Wt, lb	Vol, ft³	Wt, lb	Vol basis	Wt basis	C	Si	Mn
Before lancing									3·65	0·49	0·96
1	N and S	15	13 170	1 095	26 836	1 254	67	53	3·44	0·35	0·86
2	N and S	13	11 910	991	17 462	816	59	45	3·44	0·24	0·80

Note: Bath weight 260 tons Ore added 4·0 tons Limestone added 5·0 tons

these would be 1½ h assuming a double-stand station. This permits a 30-min cycle for each ladle, which is just adequate if desiliconizing only is contemplated. For this operation alone it would be advisable to allow for a station having four lancing positions. Four would be the minimum essential if dephosphorizing by either surface slag additions or powder injection were practised, since the blowing operation alone would be about 60 min. Plant requirements for a pretreatment operation are listed in the final section.

Active mixers pretreatment

In areas where steelmaking is based predominantly on home ores, the use of active mixers as a pretreatment process is part of the economic operation. The capacities may range between 250 and 600 tons and a melting shop may operate one or more. When used to its maximum availability, it can effectively reduce about 20% of the metalloid content of the blast-furnace iron, assist in consuming difficult types of scrap and provide an iron of regular composition to the OH furnace. The metallurgical load of the OH furnace is reduced and the output consequently increased. The increase seems to be in direct relationship to the amount of pre-refining done, particularly if Si and P are initially high. When tilting furnaces are operated on a high hot-metal charge and pre-refined iron, a more valuable slag of greater phosphoric content results.

In certain works it is not always possible to operate active mixers to the fullest advantage because of lack of capacity. In such cases oxygen pretreatment in the mixer can be of substantial benefit. It has been the subject of experimentation using oxygen alone or oxygen mixed with steam.

Experiments with oxygen in active mixer practice

At Messrs John Lysaght's Scunthorpe Works Ltd[17] trials were conducted using both methods for desiliconizing. The mixer normally contained about 250 tons of iron and before the start of the trial using oxygen alone, the bath was of the following composition: 3·50%C, 1·65%Si, 0·053%S, 1·14%P, 1·74% Mn.

Oxygen was injected through three 1-in. dia. lances at a rate of 1 460 ft³/min for a period of 65·5 min. No ore was added but an addition of limestone was made. The final bath composition was 3·22%C, 0·52%Si, 0·039%S, 1·14%P, 1·42%Mn.

After the initial desiliconizing, iron was added as received from the blast-furnaces and after each new addition oxygen was injected to control the silicon content. Occasionally ore was added before blowing. The oxygen rate was about 1 200 ft³/min for periods of 9·5–68 min depending on the quantity of new iron added and its Si content. The trials lasted for five days, treating all the iron entering the mixer. The Si content of the iron was reduced within the range 0·19–0·61%. The results are shown statistically in Table I.

The iron entering the mixer varied in temperature and quantity thus there was a fairly wide range in the bath temperatures before lancing (1 250–1 320° C) and as the quantity of Si removed also varied there was a fairly wide range of final iron temperatures. The weight of the bath was not constant and the quantity of limestone and ore charged varied according to circumstances. Despite this, there was the not unexpected evidence of a relationship between the silicon removed and the temperature increment. It was between 52° and 200° C. Si removed ranged between 0·24–1·13%. There also appeared to be a relationship between the percentage of Si removed and the roof temperature increment. The final roof temperatures were in the range 1 150–1 380° C and there was no evidence of roof damage.

Oxygen consumption averaged 250 ft³/ton equivalent to 3·12 ft³/0·01%Si/ton. If, however, the assumption is made that the decomposition of limestone provides 4 070 ft³/ton and ore 6 900 ft³/ton, the total consumption of oxygen from all possible sources was 420 ft³/ton or 5·25 ft³/0·01%Si/ton. The efficiency lies, therefore, between 98·8% and 58·8% depending on the basis employed for calculation.

The slags were monobasic containing 31·4–36·6% SiO_2 and 34·3–36·6%CaO. The iron content ranged between 4·7% and 10·7%, the average being 6·85%.

Experiments with oxygen–steam mixtures in active mixer practice

At a later date it was possible to conduct three short trials in the same mixer using different ratios of oxygen and steam. The main object was to observe the effect of steam additions on the appearance of the fume.

The oxygen–steam mixtures were introduced through two 1-in. dia. bare lances, consequently the oxygen rate was appreciably less than during the trials using oxygen alone. The results of the third trial are typical of the figures obtained and are shown in Table II.

TABLE III

Metal composition before and after pretreatment

	Element, %				Total removed
	C	Si	Mn	P	
Iron from blast furnace	4·00	1·10	0·80	1·10	
Iron after desiliconizing (I)	3·70	0·40	0·60	1·10	
Iron after desiliconizing (II) and dephosphorizing	2·20	0·05	0·10	0·10	
Elements removed (I)	0·30	0·70	0·20		1·20
(II)	1·80	1·05	0·70	1·00	4·55

The oxygen consumption was 96·4 ft³/ton for the removal of 0·25%Si. The theoretical oxygen requirement is 77 ft³/ton thus there is an efficiency of 79·8% discounting any oxygen arising from ore, limestone, or dissociated steam. The temperature increase was 60° C rising from an initial figure of 1 305° C, and the slag composition was: 34–35%SiO_2 30–35%CaO, 4·7–6·8%Fe.

The fume visible from the stack was appreciably reduced and with an approximate ratio of oxygen to steam of 50 : 50 by weight, it appeared white with a tinge of brown. It was comparable with fume issuing from a stack after hot metal additions to the furnace.

Desiliconizing in an active mixer has been shown to be a practical process. It is capable of producing iron of low and regular silicon content and is very attractive where mixer capacity is limited. The heat generated can be used to melt rough scrap or pig iron and the yield of metallic iron can be improved by additions of iron ore. Slag iron is low since the reactions can be permitted to proceed after lancing has ended. The slag fluidity and the necessity of removing slag only at intervals ensure low losses of iron from shot. There is no increase in refractory life as far as can be judged from the trials conducted and the roof temperature does not become excessive. No new capital plant is required for an installation.

Although no results have been included in the paper, it is possible to continue lancing and remove phosphorus from the iron. Additional quantities of lime and iron ore are required to provide a fluid, basic, and oxidizing slag.

Rotor process for pretreatment

Recently, two processes have acquired prominence which refine iron in vessels made to rotate during the operation. Primarily, they have been designed to produce steel from high-phosphoric Thomas iron. By modifications to the technique, iron of any composition can be converted. Each has a basic lining and uses oxygen as the primary refining agent. Because of their high thermal efficiency both processes are capable of absorbing appreciable quantities of iron ore or steel scrap. This is particularly true when producing steel since the carbon monoxide involved burns to carbon dioxide above the surface. During rotation the heated surface of the lining is carried below the metal surface and thus returns a proportion of the heat to the bath.

In construction there are differences in the two methods and to some extent in operation. The Swedish Kaldo has a relatively large ratio of diameter to length whilst the German Oberhausen Rotor has a small diameter, but is comparatively long. The former is made to revolve at speeds up to 30 rev/min and the latter at 0·5 rev/min.

TABLE IV

Estimated metal and metalloid losses during pretreatment

Source of loss	Weight, cwt/ton	
	Desiliconizing	Desiliconizing and dephosphorizing
Metalloid removal	0·24	0·91
Iron in slag	0·08	0·40
Iron as shot	0·18	0·18
Iron as fume	0·09	0·25
Total losses cwt ton	0·59	1·74
Deduct iron from mill scale		0·94
Nett losses cwt/ton		0·80
Iron required to produce 1 ton of pretreated metal		
Desiliconizing		20·61 cwt
Desiliconizing and dephosphorizing		20·83 cwt

The Kaldo operates with a single jet of oxygen above the surface, but the Oberhausen plant employs two jets, one above and the other below the metal. High-purity oxygen is used in the Swedish plant, but the German plant employs 95% purity oxygen below the surface and 73% purity oxygen above the surface.

When using Thomas iron containing 0·40–0·60%Si and 1·8–2·0%P, a pre-refined iron can be produced in about 40 min blowing containing around 1·0%C and 0·10%P. Each plant is capable of being operated on a 100-tons scale so that such a quantity of fully pretreated iron could be available every 80–90 min.

The slags are reasonably low in iron (8–12%) and the metallic yield is good because of the large ore additions. Using Thomas iron or basic iron containing 1·2–1·4%P, a useful phosphoric slag is available

TABLE V

Plant items and capital cost for pretreatment stations

Plant items	Desiliconizing	Desiliconizing and dephosphorizing
Metal ladles 80 tons nominal capacity	6	9
Slag ladles 20 tons capacity	4	4
Hoods	4	6
Fume cleaning plant	1	1
Oxygen lances and hoists	6 (2 spare)	8 (2 spare)
Instrument panels	1	1
Grinding plant	...	1
Dispensing plant	...	1
Buildings	1	1
Estimated total cost	£150 000	£230 000

TABLE VI

Raw materials prices for pretreatment processes

Material	Price, shillings/ton
Blast furnace iron	280
Steel scrap	240
Limestone	25
Lime	100
Millscale	140
Lances	9d ft
Oxygen	6s/1 000 ft³

as a material credit. Sulphur reduction is good in each process, amounting to 60% of the initial 0·05–0·06%.

Under certain conditions the rotor processes may prove economical as pre-refining units particularly if the slag can be turned into a credit instead of a debit cost. The capital cost of a plant is, however, high as may be maintenance and refractory costs. It is not considered that either process will find wide adoption as a pre-refiner but will fulfil their intended roles of efficient steelmaking units.

ECONOMICS OF LADLE PRETREATMENT

In the preceding section most of the methods of pretreatment have been described and each has its particular advantages.

In certain cases the methods have not been developed on a full commercial scale and the costs have not been accurately determined. An estimate has been given[9] for runner desiliconizing of 176 francs (3*s*) per ton for a reduction in silicon of 0·25%. This is regarded as the minimum and would be higher if greater silicon reduction is required. The cost refers to conditions in France in 1957.

TABLE VII

Comparative cost of metal after desiliconizing and dephosphorizing

	Desiliconizing		Desiliconizing and dephosphorizing	
	Quantity per ton	Cost per ton s d	Quantity per ton	Cost per ton s d
Material cost				
Blast furnace iron	15·61 cwt	218 6	15·83 cwt	221 7½
Steel scrap	5·00 cwt	60 0	5·00 cwt	60 0
Limestone	56 lb	6½		
Lime			250 lb	11 2
Millscale			150 lb	9 5
Total material cost		279 0½		302 2½
Operating cost				
Labour		5		7
Maintenance		1 0		1 0
Services		9		9
Oxygen	300 ft³	1 9½	1 200 ft³	7 2
Lances	1 ft	9	1½ ft	1 1½
Additional refractories				6
		4 10½		11 1½
Capital	10%	4½		8
Total pretreated iron cost		284 3½		314 0

TABLE VIII

Actual cost of pretreatment processes

	Desiliconizing		Desiliconizing and dephosphorizing	
Weight of metal required to offset metalloid removal	20·24 cwt		20·91 cwt	
	Quantity, cwt	Cost per ton s d	Quantity, cwt	Cost per ton s d
Blast-furnace iron	15·24	213 4	15·91	222 9
Steel scrap	5·00	60 0	5·00	60 0
Metallic cost	20·24	273 4	20·91	282 9
Total pretreatment cost Table VII		284 3½		314 0
Actual cost of pretreatment process		10 11½		31 3

The rotor processes have been described only in brief because of their technical interest as it is considered that they will be used predominantly for steelmaking rather than pretreatment. The capital investment of a composite plant consisting of rotors, inactive mixers, and open-hearth furnaces would be unjustifiably high for them to be considered except in isolated instances. The cost of active mixer operation has been discussed on several occasions and it is not proposed to review the subject again.

There remain the ladle pretreatment processes and it is proposed to discuss the probable cost of removing silicon alone and silicon and phosphorus from molten iron by this method. An assessment of this nature must be quite general since costs of different operations and methods of costing vary between different works. It is hoped, however, to indicate the costs which can be modified to suit the conditions in particular works.

Pretreatment processes may be introduced in an existing steelworks or incorporated in a new steelmaking project. Cost differences would arise because of capital outlay and output. The first would be apparent because in an older works a site has to be adapted to take a new process whilst in a new steelworks scheme it can be incorporated in the basic plan. It will be seen, however, that capital investment is not particularly large even when considering large-scale operation. Therefore this variable is not very significant. In older works the output is small by modern conceptions and therefore this variable may alter the estimated cost since the assessments have been based on a new works producing 1·0 million tons of ingots per year. The iron make has been taken as 750 000 tons all of which it is proposed to pretreat.

When considering desiliconizing it has been assumed that limestone would be used as a flux and added in lump form to the ladle. In the case of desiliconizing and dephosphorizing the cost has been based on using

lime and millscale mixed together and injected below the metal surface with the oxygen stream. Allowance has been made in the capital cost for powder-dispensing and flux-grinding plants. It has been assumed that the iron is of the same analysis for each process and that the initial and final compositions will be as shown in Table III. In both processes metallic losses will occur due to iron combined in the slag as shot or in the form of fume. The losses have been assessed in Table IV.

In each case it is considered that 5 cwt of scrap may be added per ton of metal produced to control the metal temperature. No reduction in ladle life has been considered for desiliconizing, but the cost of basic linings and a shorter ladle life has been included when the process includes dephosphorizing. A life of 80–100 heats has been taken for the former and 50–60 heats for the latter. Table V gives a list of the plant items and the total capital costs for the two types of plants.

Although in small-scale dephosphorizing experiments bauxite or fluorspar have been used to assist in producing fluid slags, the practice has not been included because the mass effect should give sufficient heat to create the desired slag fluidity.

The material costs have been based on the prices given in Table VI. Labour costs have been based on wages rates of £12–14 per 42-h week per operator. The final cost summary is made in Table VII.

By reference to Table IV it will be seen that losses occur either by metalloid removal which is the object of pretreatment, or as iron in the slag, shot, or fume. These losses mean that more than 1 ton of iron is required to produce 1 ton of pre-refined metal. The loss due to metalloid removal is necessary and unavoidable, but is reflected in the cost. In an operating cost assessment, it should not be included since it is common to all methods of turning blast-furnace metal into steel.

During desiliconizing the metalloid loss is 1·20% which means that for 20 cwt of desiliconized metal 20·24 cwt of pig iron and scrap are required. Similarly for desiliconized and dephosphorized metal the quantity is 20·91 cwt. The cost of these may be termed the 'standard mixture costs,' which must be deducted from the total cost to arrive at the cost of the pre-refining operation. The effect is shown in Table VIII.

CONCLUSIONS

From the data available it is technically possible to carry out pretreatment processes in a number of different ways. The simplest methods are considered to be either in transfer ladles at specially constructed pretreatment stations or in active mixers. The estimated cost of removing silicon to 0·40% and the complete elimination of silicon and phosphorus down to 0·10% have been prepared. It is considered that these compare very favourably with active mixer operations largely because of the lower investment costs. A comparison with rotor methods would also appear to be favourable.

ACKNOWLEDGMENTS

The author wishes to record his thanks to the Directors of British Oxygen Gases Ltd for permission to publish the paper and to his colleagues in British Oxygen Research and Development Ltd for their valuable help in its preparation. Thanks are also due to Messrs John Lysaght's Scunthorpe Works Ltd and to l'Institut de Recherches de la Sidérurgie for permission to use certain results.

REFERENCES

1. D. F. MARSHALL: *JISI*, 1952, vol. 172, pp. 315–326.
2. L. COOK: *Ibid.*, 1955, vol. 179, pp. 1–17.
3. A. JACKSON, in report of BISRA 39th Steelmaking Conference, October, 1952.
4. J. GIBSON: *Iron Steel*, 1956, vol. 29, pp. 55–59.
5. E. A. WHEATON: *AIME Proc. O H Comm.*, 1940, vol. 20, pp. 151–154.
6. S. F. ELAM: *Ibid.*, 1949, vol. 32, pp. 87–92.
7. W. J. B. CHATER and J. A. CHARLES: *JISI*, 1959, vol. 191, Apr., pp. 319–328.
8. I. L. BELL: *Ibid.*, 1878, vol. 1, pp. 17–34.
9. P. LEROY and R. SIMON: *Rev. Met.*, 1957, vol. 54, pp. 793–812.
10. E. DAVIES: *Iron Coal Trades Rev.*, 1956, vol. 172, pp. 987–988.
11. *Ibid.*, 1951, vol. 163, p.300.
12. S. R. ISAAC: *JISI*, 1955, vol. 181, pp. 44–48, and discussion, 1956, vol. 183, pp. 79–80.
13. J. A. CHARLES, W. J. B. CHATER, and J. L. HARRISON: "Oxygen in Iron and Steel Making": 1956, London, Butterworth.
14. K. HEINRICH, in discussion: *Rev. Univ. Min.*, 1953, ser. 1, vol. 9, pp. 637–639.
15. W. WOLF *et al.*: *Stahl Eisen*, 1958, vol. 78, pp. 1 100–1 107.
16. *Iron Coal Trades Rev.*, 1956, vol. 173, pp. 1 539–1 541.
17. Private communication from John Lysaght's Scunthorpe Works Ltd.
18. *Iron Coal Trades Rev.*, 1955, vol. 171, pp. 319–323.
19. LA. A. SHNEEROV *et al.*: *Stal*, 1958, no. 8, pp. 694–702.

Industrial Publications Received

The English Electric Co. Ltd., have recently published four booklets: SG/251 on "Frame g" air-blast circuit breakers; ST/117 on non-reheat steam turbines of 10 MW and above; ST/121 on geared steam turbo-generating sets with outputs of 750–5 000 KW; and WA/141 on the "Hermes" electrode for welding heavy sections in mild, medium high-tensile, and carbon and alloy steels.

Recent catalogues from Hilger and Watts Ltd. deal with direct-reading spectrographs (CH 405/2), digitizers and other equipment for data processing, and synthetic crystals (CH326/4).

Publication no. RD85 from the Morgan Refractories Ltd. is devoted to Tri-Mor Dense Guncrete.

Kaye Alloy Castings Ltd. celebrate their 20th anniversary with the publication of a glossy brochure illustrating the stages through which their die castings pass before leaving the foundries.

Production grinding machines are the subject of publication no. 236D from A. A. Jones and Shipman Ltd.

F. H. Lloyd and Co. Ltd. has issued a pamphlet describing the radiographic services available at their James Bridge Steel Works, Wednesbury.

Catalogues G/45/1 on indicating, recording, vacuum, pressure, and differential gauges and H 20/2 on hygrometers have been issued by Negretti and Zambra Ltd.

A brochure on motor control centres has been received from Igranic Electric Co. Ltd.

From the Cambridge Instrument Co. Ltd. comes a data sheet on the "Centre Line" indicator-controller (List 28) and a pamphlet (List 144/A) on general principles of gas analysers.

James Neill and Co (Sheffield) Ltd. have issued a valuable 48-page booklet by F. G. Tyack, A.M.I.E.E., entitled "Permanent Magnets Summarized."

The use of oxygen in a modified tilting furnace: a progress report

By A. Jackson, Assoc. Met., F.I.M., C.G.I.A.

SYNOPSIS

The paper describes the results of a year's operation of a modified tilting furnace (Ajax furnace). Details are given of refractory replacement and the costs are compared with standard practice. Details are also given of lance life, gas-cleaning equipment, and the waste-heat boilers. The results show that the process gives increased output, decreased ingot cost, and greater flexibility of steelmaking. 1698

THIS PAPER gives the operating results of one year's working and further experience acquired since that recorded in the previous publication to the Institute as shown in the *Journal* for September, 1958.

The production gain is calculated in relation to silica roof practice, and then for comparison with basic roofs which were introduced on the other furnaces during the same period as the oxygen developments. These comparisons are shown below under the heading 'working week.'

The column headed 'yearly average' is based on the 'working week' production, but corrected for furnace availability.

	Working week	*Yearly average*
Silica furnace roof	100%	100%
Basic furnace roof	111%	111%
Ajax, basic roof and oxygen	150%	140%

The record week on the furnace was 5 332 tons and the record cost period (4 weeks) 19 263 tons. The present estimate of its annual production based on the more recent output figures is 195 000–200 000 tons.

Although repairs are frequent, as shown by the availabilities figure shown in Table I, they are short so that a relatively uniform period production is obtained. This is shown in Fig. 1 which compares the operation of the same furnace in the year before the changeover using basic roofs, with the production since January, 1958 when the oxygen modification came into operation. The first two periods had low production arising from teething troubles and training the melting-shop personnel in operating the new process.

The mixtures shown in Table I are about the optimum for the two processes, i.e. the normal open-hearth furnace would produce at a much lower rate on 100% hot metal. The Ajax process has used up to 20% scrap, but suffers a small loss in production because the extra charging time is greater than the decreased blowing time necessary.

The fuel used is entirely coke-oven gas and the quantity includes 'heating up' the furnace after repairs.

Manuscript received on 23rd February, 1959.

Mr Jackson is Technical Director of the Appleby-Frodingham Steel Company and Technical Adviser on Steelmaking to the United Steel Companies Ltd.

Oxygen used in lancing is about 950 ft³/ton, the remainder being for combustion including 'heating up'. The total cost of oxygen and fuel is about 43% of that of the normal furnaces. Dolomite shows a small reduction in consumption.

The figures for lime and limestone are averages for the whole period under consideration. During the first few months the ratio of lime to limestone was 0·66 to 0·27 cwt/ton respectively. In the latter months this was changed, without apparent disadvantage to the process, but with reduced cost of fluxes, to lime 0·39 cwt/ton, limestone 0·87 cwt/ton.

REFRACTORIES

The refractory cost for the Ajax furnace is almost identical with standard practice. The roof cost, however, is very much greater, but the total of linings, ports, uptakes, slag pockets, and chequers is correspondingly much less.

The roof installation is the same as standard 'all basic' furnace practice (*see* Fig. 2).

Patching over the lances is much too frequent and the cooling necessary cannot fail to be a disadvantage to the rest of the roof. Furthermore, patches are often much larger than necessary, because the thicker bricks at the side of the hole cut for patching often 'run away' and so need a much larger replacement area than was warranted by the extent of the roof wear. This difficulty has been overcome to a significant degree by methods of support during patching, but the experiments continue.

Patching offers no more difficulty than for silica furnaces and is carried out in the same way. The most important thing is to knock out the hole to the desired size and shape with the furnace as hot as possible, even if it is necessary later to wait a little while for cooling to enable support gear to be fixed and the men to get to work.

The hearth lining lasts much better now, in the absence of silica drip, and does not appear to be attacked by slag splash.

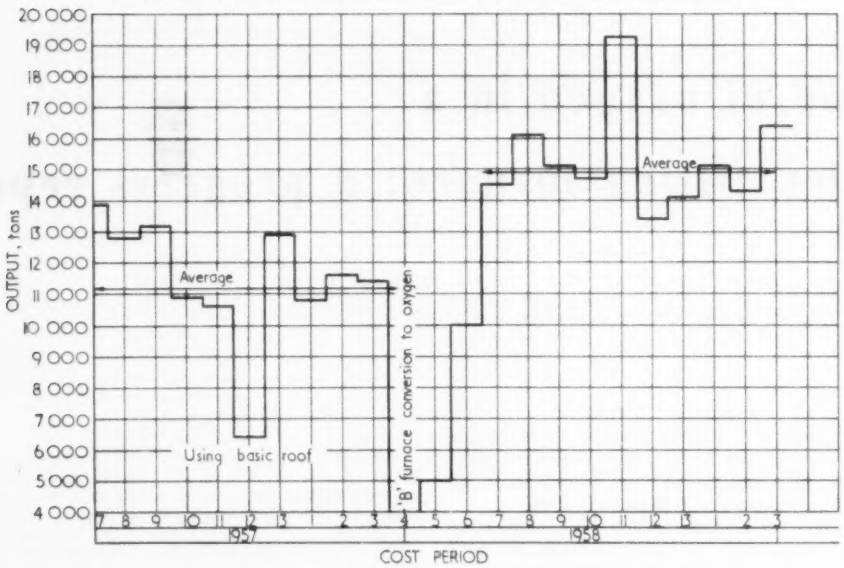


Fig. 1—Comparison of output before and after conversion to oxygen

The port ends last well, and changing is so simple that they are left on even after a furnace repair if a week's life remains in them. They are then patched, mainly at the point of waste-gas impact. The base of the port which gets slag covered will last many months.

The slag pockets were built originally entirely in mag-chrome brick. This failed quite rapidly by spalling around the eye where the uptake joins the top of the slag pocket, and led to frequent collapses.

Experience also showed that the temperature in the slag pocket was less than originally expected. Construction has now been modified and the upper half of the downtake, the eye and slag pocket roof around it, have been built in silica which stands up better because the bricks frit together in use. The base of the uptake, on which slag is desposited, remains basic brick because of its superior resistance to slag attack.

When the slag pocket needs relining in its entirety it is proposed to build the roof in silica, but keep the lower half in basic brick. Operations so far have not rendered this relining necessary, but when the roof does collapse it will be due to continued spalling and not to damage by heat alone.

The regenerator temperatures have an alarm which operates when the top temperature exceeds 1 250–1 275° C and the furnace is reversed. Only a very few chequer bricks in the top course or two have been replaced during a year's working. Firebricks (42% Al_2O_3 type) will be tried as a replacement for silica when the top courses need replacement.

Normally, regenerator chambers and slag pockets are allowed to run for 4 weeks. During this time the bottom of the chequers accumulates a significant amount of flue dust, although this never appears to be sufficient to impede seriously the draught at this point. Arrangements are now being made for the introduction of steam blowers to agitate this dust so that it is carried away by the waste gases and eventually collects in the gas cleaner, which is a more convenient point at which to deal with it.

SLAG POCKETS

As the pocket slag is removed by two men in a cold state it is easy to collect, weigh, and sample it, before returning it to the ironworks for charging to the blast furnace.

Table II gives the averages of 14 samples taken by approved sampling methods and by comparison an average sample from the four pockets of two normal furnaces with ends built essentially in silica brick.

The various samples on the Ajax furnace gave reasonably close agreement. Normal furnaces vary widely both in separate chambers and in the averages of four pockets.

PORT ENDS AND UPTAKES

The port ends themselves have been changed whilst the furnace is working, and the minimum time taken was 7 min. The average is about 30 min, this was increased on the odd occasion when other difficulties delayed the change.

TABLE I

Comparative results based on a working year

	Type of furnace		
	Silica roof	Basic roof	Ajax
Production per working week	2 889	3 210	4 316
Annual production divided by 52 weeks	2 600	2 889	3 623
Furnace availability	90%	90%	84%
Ingot yield	90%	90%	87·2%
Scrap cwt ton ingots	3·55	3·55	0·20
Molten metal ,,	17·01	17·01	21·50
Oxides ,,	2·23	2·23	1·58
Lime ,,	0·21	0·21	0·53
Limestone ,,	1·45	1·45	0·55
Dolomite ,,	0·64	0·64	0·56
Oxygen, ft³ ton	160	160	1 380
Therms ton	45	47	11

To change completely both uptakes and the port ends needs 3½ h, but this is only done either when the furnace is off for a general repair or when it requires a major patch on the roof. Hot spots on the uptake and the top of the slag pocket can be kept cool by the application of water sprays whenever necessary, thus the changeover can be made as and when convenient without interference with the normal operation of the furnace.

During the whole of the time the furnace has been operating it has been unnecessary to lose any time due to repairs to either the slag pockets or the regenerator chambers. The length of time necessary to put in hearth linings or put on the roof represents the total time the furnace is out of commission.

GAS CLEANING

The plant is now using glass-fibre filter bags and the average life was 12–14 weeks for the first complete run.

No cooling air is used, the products of combustion at 200° to 240° C pass directly from the waste-heat boiler to the gas cleaner.

The cyclones designed to collect the coarse dust before entry to the bag filters have been removed to reduce the resistance to gaseous flow. The fan output has also been increased somewhat so that the plant now passes a measured volume of 750 000–800 000 ft³/h (N.T.P.) which includes the counter-blast air of about 6·5% of the total.

The gas cleaner does not clean the whole of the waste gases leaving the furnace; measurement has shown that the amount actually passing through varies from 66% to 95%, the remainder going through the by-pass to the chimney.

Under these circumstances, the total amount of dust collected is averaging 12 tons/week. If it is assumed that the average volume passing through the cleaner is no more than the minimum, this gives a figure of about 18 tons/week or 9 lb/ton.

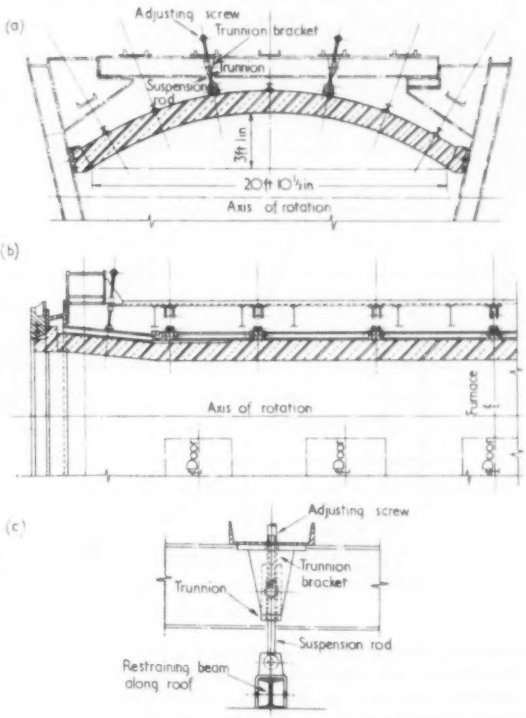
To this must be added the quantity collected from the flues which are cleaned out at relatively long intervals. This has been weighed and the figure is 2·5 lb/ton which is very little in excess of the normal O H figure of 2·2 lb/ton ingots.

The analysis of the dust from the Ajax gas cleaning plant is as follows:

TABLE II

Slag pocket analyses

	Ajax Av. 14 samples	'O' Furnace, Av. 4 pockets	'R' Furnace, Av. 4 pockets
	%	%	%
SiO_2	4·5	32·0	44·3
Al_2O_3	1·7	1·2	0·6
MnO	0·9	0·9	0·7
CaO	13·2	14·0	15·2
MgO	15·8	5·5	9·3
Cr_2O_3	2·6	not estd.	not estd.
S	0·03	0·03	0·02
P_2O_5	4·9	2·2	2·1
FeO	7·0	4·5	5·7
Fe_2O_3	49·0	37·0	20·0
Fe	40·0	29·4	18·4
lb/ton ingots	11·0	12·7	13·5



(a) Cross-section through furnace roof
(b) Half longitudinal section through roof
(c) Typical arrangement of restraining gear

Fig. 2—Roof installation

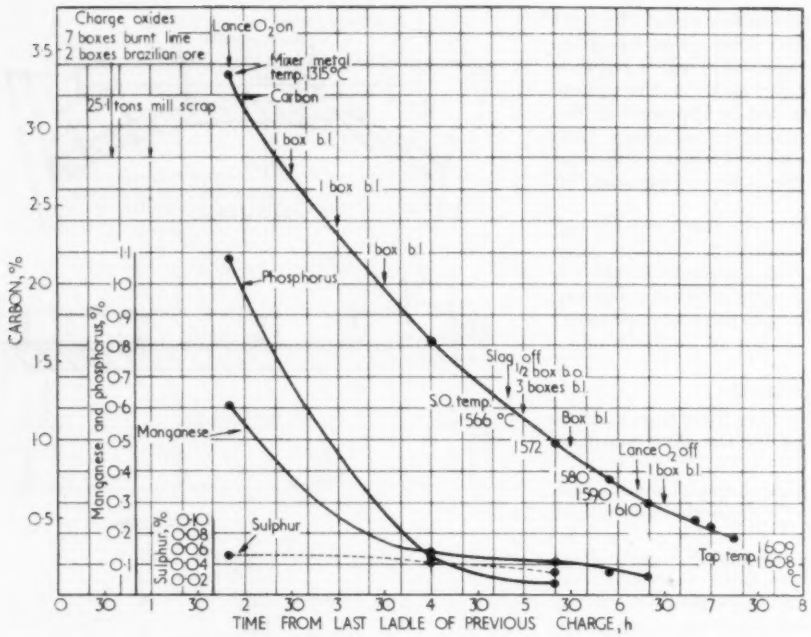
Dried at 100° *C*	%
Ferric Oxide	93·95
Ferrous Oxide	0·78
Insoluble	0·28
Alumina	0·13
Lime	0·65
Magnesia	0·54
Phosphoric Acid	1·15
Manganous Oxide	0·85
Total Sulphur	0·616
Sulphate Sulphur	0·615
Carbon Dioxide	0·13
Combined Water	0·71
Titanium Oxide	Trace
Copper	0·11
Total Carbon	0·23
Total Iron	66·37

It is interesting to note that reports indicate the collection of 6–7·5 lb of dust/ton of ingots from normal O H furnaces abroad which use dust cleaning plant.

LANCE LIFE

The life of the lance is extremely variable, from a minimum of one charge to a full week. The reasons for sudden failure are not clear, nor is the precise time during the charge when the lance begins to leak. Almost invariably the hole is small and blowing can continue until the furnace taps, when the lance can be changed without delaying the operation.

An investigation by the Works Study Department has resulted in the introduction of a standard method of changeover with the minimum time of 35 min, but which can always take place during tapping and



Charge 670

220 tons hot metal charged 6·50 h tap-to-tap. 33·85 tons/h 198 000 ft³ lance O_2 used in 4·42 h Ordinary quality steel made Pit sample:

Element, %			
0·17–0·18C,	0·030P,	0·64Mn,	0·044S

Fig. 3—Removal of sulphur and phosphorus during the Ajax process

charging the furnace, without any delay. Experience has shown that the lance can be immersed in the metal without causing it to leak. Furthermore, it has been shown to be impossible to damage it by applying an oxy-acetelene flame to the tip with full water flowing.

Experiments are being made in an effort to find the best angle of impact of the oxygen jet on the bath. Information is being acquired but no final result is yet available.

WASTE-HEAT BOILERS

The waste-heat boiler needs constant attention if the tubes are to be kept clean. The economizer is particularly vulnerable to blockage, and unless this is dealt with, the pressure loss becomes sufficient to prevent the furnace having all the draught it requires during the time it is firing fuel.

The production of steam is only 205 lb/ton against 1 024 lb on the adjacent normal furnace. If this is calculated to indicate the percentage of Btu's in the fuel which is recovered as steam, the figures are respectively 27% and 28%. The value of the steam credit, after paying for the boiler costs, is about the same as the cost of gas cleaning.

STEELMAKING

Compared with normal tilting furnace practice at Appleby-Frodingham the Ajax process is characterized by the ease with which phosphorus is removed leaving only carbon in the bath to be dealt with towards the end of the process. This characteristic is especially noticeable when it is desired to produce medium to high-carbon steels by tapping on carbon. With normal O H practice, and at the phosphorus content prevailing, this was very difficult to achieve. With the Ajax process, however, it is relatively simple. This is illustrated in Figs. 3 and 4. In one instance is shown the rate of fall of carbon and phosphorus, in particular for ordinary steel, whilst the other demonstrates the operation of a charge of higher carbon steel which it is intended to tap on carbon and aims to have a relatively low phosphorus and sulphur content in the finished steel.

Sulphur removal

Unless a special effort is made to remove sulphur, the Ajax furnace gives a pit sample sulphur very similar to that of other furnaces in the shop with the same sulphur in the metal as charged. In this connection it must be remembered that the Ajax furnace when firing fuel uses 100% cold coke-oven gas which is high in sulphur, whereas the other furnaces use a portion of creosote pitch along with the coke-oven gas.

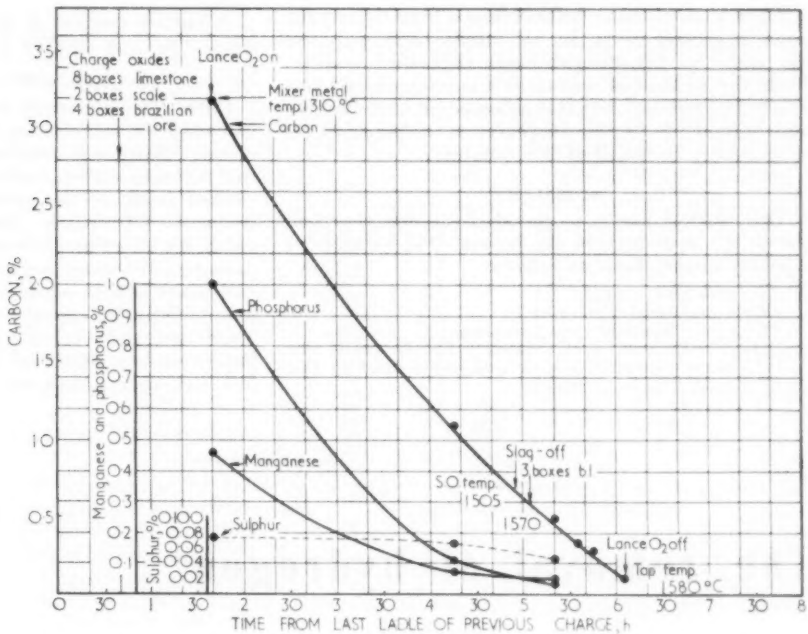
When the sulphur in the metal at 'slag-off' is high, however, it can be removed steadily and positively in the oxygen furnace by the addition of successive boxes of burnt lime. The other furnaces exhibit the variability of sulphur removal which characterizes normal O H furnaces in spite of the addition of what appears to be the requisite amount of lime.

If low sulphur in the steel is necessary, then this

TABLE III

Sulphur and phosphorus contents of charges made in the oxygen furnace

Charge metal		Pit sample	
Sulphur, %	Phosphorus, %	Sulphur, %	Phosphorus, %
0·053	1·07	0·018	0·020
0·071	0·82	0·029	0·025
0·053	1·05	0·023	0·031
0·064	1·08	0·026	0·020



Charge 740
25·1 tons scrap 195 tons hot metal charged
7·58 h tap-to-tap. 29·04 tons/h
216 000 ft³ lance O_2 used in 4·40 h
0·37–0·39%C upending quality steel made
Pit sample:
Element, %
0·39C, 0·020P, 0·89Mn, 0·018S

Fig. 4—Removal of sulphur and phosphorus during the Ajax process

can undoubtedly be done more positively on the oxygen furnace during lancing than is possible in the normal steelmaking furnaces. Table III gives examples of charges made by this method.

'Slag-off-slag' analyses

The problem of slag composition and iron loss can be illustrated by the figures shown in Table IV.

These are separated into two major groups, the first between July and September comprising 188 charges, and the second from September to December with 175 charges.

Each major group is shown under three sub-groups, i.e. under 10% iron in the slag, 10–17%, and over 17%.

To conform with our standard O H practice we would like all slags to be under 10%. In fact only 11% were below this figure in the first group, but this had increased to over 16% in the second. This shows that it is possible, without slowing down the process, to produce slags low in iron and in conformity with our normal practice, although in this case the P_2O_5 content as shown is considerably higher.

It is obvious that an Fe content below 10% could be achieved if oxygen blowing ceased before 'slag-off', and the furnace was allowed to come to equilibrium under a normal gas flame, as in our ordinary practice. The time taken to do this, however, retards the process to such a degree that the loss due to increased tap–to–tap time is greater than the saving made by reducing the iron content of the slag.

TABLE IV—Slag analyses

July 2nd–Sept. 14th 1958, (188 charges)	Composition, %							
Group	Fe	SiO_2	CaO	MgO	P_2O_5	Sol^y	S	P_2O_5 + SiO_2
Under 10% Fe	8·2	7·9	43·2	8·70	22·59	95·1	0·094	30·49
10–17% Fe	14·5	5·8	40·1	8·62	20·46	92·9	0·098	26·26
Over 17% Fe	21·2	4·2	37·8	9·6	16·76	93·9	0·123	20·96
Sept. 14th–Dec. 7th, 1958, (175 charges)								
Under 10% Fe	8·8	6·9	41·7	7·4	24·99	90·2	0·060	31·89
10–17% Fe	14·7	5·8	38·7	8·17	21·58	90·1	0·082	27·38
Over 17% Fe	21·4	4·2	36·0	9·1	17·7	90·8	0·105	21·90

STEEL DEFECTIVES

Over a period of several months the defectives attributed to steelmaking in the section and plate mills were carefully segregated for the Ajax furnace in comparison with standard practice.

These mills consist of a slab mill, a 12-ft and a 7-ft plate mill and cogging mill, a 32-in. and 15-in. section mill.

The figures for these individual mills showed slight variations in that in some the defects were slightly in favour of the oxygen-blown furnace, whilst in others the effect was the opposite. The differences, however, were small.

When the steel defects were totalled separately for all plates and all sections including the three mills in each group, then the total at loss of defectives calculated on ingot weight were slightly better for the oxygen-blown steels.

GASES IN STEEL

A series of casts were examined to enable them to be compared with normal steel in all mills.

These showed that results obtained from the oxygen lancing process were to all intents and purposes the same as the normal basic O H steel quality. From the method of operation it is obvious that this was to be expected, but this information was collected and submitted to the Inspectorate responsible for steel testing on behalf of the customer.

SUMMARY

This process has now operated for one year and shown its superiority to the normal O H furnaces at Appleby-Frodingham as follows:

(1) increased output
(2) a decreased ingot cost
(3) better flexibility in steelmaking
(4) it still has very considerable potential for improvement if the difficulties outlined in this paper can be overcome.

A further furnace is now being converted to the Ajax type, and another is planned to follow.

ACKNOWLEDGMENTS

During the year many experiments have been made including the use of scrap and/or direct blast furnace metal. Many new men have been trained to operate the furnace, whilst bricklayers and engineers have worked hard on the problems associated with the frequent roof repairs. The technical staff have also put much effort into overcoming many snags and the drawing office much work on design. To all of these, and many others, must be given credit for what is, undoubtedly, an advance in our steelmaking process. There are, however, still so many obvious potential improvements, that until these are made no-one will feel that success has really been achieved.

The removal of hydrogen by diffusion from large masses of steel

By J. D. Hobson, Ph.D., F.R.I.C., A.I.M.

SYNOPSIS

A method for using the known diffusion constants of hydrogen in iron to calculate the rate of loss of hydrogen from large masses of steel is described. The theoretical approach is based on the use of published tabular solutions of heat flow equations, and an analogy between heat flow and hydrogen diffusion. Typical theoretical calculations for forging, annealing and heat-treatment cycles are given, and comparisons of calculated and observed results are made for a number of practical cases. 1583

IN THE MANUFACTURE of large alloy-steel forgings it is usual to allow long annealing cycles for the removal of hydrogen by diffusion, the actual times and temperatures being based on custom and experience. Similarly the production of rolled billets in alloy steel frequently requires some form of slow cooling or annealing, if the formation of hairline cracks is to be avoided. In both cases there are probably several processes involved, each of which may contribute to the production of sound material, and these include (*a*) the loss of hydrogen by diffusion and (*b*) the relief of transformation stresses. There is evidence in the literature that hydrogen is closely connected with the various defects known as hairline cracks, shatter cracks, fisheyes, etc., though whether hydrogen alone is solely responsible is still debatable. However, there is no doubt that such defects can be prevented by suitable heat-treatment cycles designed to bring about the processes mentioned, in which the removal of hydrogen is a factor of first importance. A method of calculation of the losses of hydrogen during the forging, annealing, and heat-treatment of large masses of steel would therefore be of considerable use, and the following sections describe the development of a theoretical approach and its practical application to the problem.

Manuscript received on 14th May, 1958.
The author is with Hadfields Ltd.

HYDROGEN DIFFUSION CONSTANTS

In their paper on hydrogen in steel manufacture, Sykes, Burton, and Gegg[1] calculated values for the diffusion constant of hydrogen in α- and γ-iron at a number of temperatures, starting from the solubility results of Sieverts[2] and permeability determinations of Smithells and Ransley,[3] and inferring that heat flow equations could be applied to problems of hydrogen diffusion. Using the tables of Russell[4] for heat

flow, but without giving details of the mathematical method, they compared the theoretical and experimental rates of loss of hydrogen from steel specimens and showed that at elevated temperatures there was agreement within a factor of about 1·5, but that at room temperature the practical times were very much longer than predicted by theory. Following up this observation, it has been shown by Hobson[5] that the exponential law connecting diffusivity and absolute temperature fails below about 150° C, and that the diffusion rate at RT is reduced to about one-fiftieth of that predicted theoretically.

The diffusion constants given in Table I have been taken from the results of Sykes *et al.*, with additional values calculated where necessary, and corrections derived from practical experiments applied to values of the constant below 200° C.

Mathematical treatment of problem of hydrogen diffusion

The theory of heat flow in simple bodies, for example infinite plates and cylinders, has received considerable attention and certain cases can readily be solved by use of the tabulated results given by Russell.[4] The flow of heat and hydrogen diffusion may be treated by a common mathematical method, provided that the physical constants are known and are correctly equated in the analogue treatment, and that the simplifying assumptions necessary for mathematical treatment are valid.

Following the part of Russell's paper relating to heat flow in an infinitely long cylinder, and assuming Newton's Law of Cooling to hold:

$$\frac{dQ}{dt} = K \cdot \frac{dT}{ds} \quad \ldots\ldots(1)$$

where K is the thermal conductivity of the material at temperature T and dT/ds is the temperature gradient. From this equation the fundamental partial differential equation in three directions at right angles is deduced:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{S\rho}{k} \cdot \frac{\partial T}{\partial t} \quad \ldots\ldots(2)$$

where S and ρ are the specific heat and density of the material at temperature T.

Transferring to cylindrical coordinates gives:

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \cdot \frac{\partial T}{\partial r} + \frac{1}{r^2} \cdot \frac{\partial^2 T}{\partial \theta^2} + \frac{\partial^2 T}{\partial z^2} = \frac{S\rho}{k} \cdot \frac{\partial T}{\partial t} \quad \ldots(3)$$

For a cylinder heated symmetrically about its axis:

$$\frac{1}{r^2} \cdot \frac{\partial^2 T}{\partial \theta^2} = 0 \quad \ldots\ldots(4)$$

and the equation becomes:

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \cdot \frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2} = \frac{S\rho}{K} \cdot \frac{\partial T}{\partial t} \quad \ldots\ldots(5)$$

or omitting end-effects:

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \cdot \frac{\partial T}{\partial r} = \frac{S\rho}{K} \cdot \frac{\partial T}{\partial t} \quad \ldots\ldots(6)$$

Russell gives the solution of this differential equation as:

$$U = \sum_{n=1}^{n=\infty} A_n e^{-M_n^2 \tau} J_0(M_n R) \quad \ldots\ldots(7)$$

TABLE I

Variation of the diffusion constant of hydrogen in α- and γ-Fe with temperature

Temperature, °C	Diffusion constant k, cm²/s		Time-diffusion product, kt/h	
	α-Fe	γ-Fe	α-Fe	γ-Fe
1 500	$3{\cdot}9_6 \times 10^{-4}$	$5{\cdot}0_7 \times 10^{-4}$	$1{\cdot}43$	$1{\cdot}90$
1 400	$3{\cdot}8_8$,,	$4{\cdot}1_3$,,	$1{\cdot}38$	$1{\cdot}49$
1 300	$3{\cdot}6_5$,,	$3{\cdot}3_0$	$1{\cdot}31$	$1{\cdot}19$
1 200	$3{\cdot}4_4$,,	$2{\cdot}5_0$,,	$1{\cdot}25$	$0{\cdot}90$
1 100	$3{\cdot}2_8$,,	$1{\cdot}9_0$,,	$1{\cdot}19$	$0{\cdot}68_4$
1 000	$3{\cdot}0_5$,,	$1{\cdot}3_0$,,	$1{\cdot}11$	$0{\cdot}46_5$
900	$2{\cdot}8_4$,,	$8{\cdot}7 \times 10^{-5}$	$1{\cdot}02$	$0{\cdot}313$
800	$2{\cdot}6_8$,,	$5{\cdot}7$,,	$0{\cdot}97$	$0{\cdot}205$
700	$2{\cdot}3_4$,,	$3{\cdot}1$,,	$0{\cdot}84$	$0{\cdot}112$
600	$2{\cdot}0_4$,,	$1{\cdot}5_4$,,	$0{\cdot}73_5$	$0{\cdot}056$
500	$1{\cdot}7_6$,,	$6{\cdot}4 \times 10^{-6}$	$0{\cdot}61_2$	$0{\cdot}023$
400	$1{\cdot}3_5$,,	$2{\cdot}0$,,	$0{\cdot}49_7$	$0{\cdot}007$
300	$1{\cdot}0_5$,,	$4{\cdot}3 \times 10^{-7}$	$0{\cdot}36_0$	$0{\cdot}00_2$
200	$6{\cdot}7 \times 10^{-5}$	$4{\cdot}7 \times 10^{-8}$	$0{\cdot}24_1$	...
100	$1{\cdot}3_2 \times 10^{-5}$*	$1{\cdot}5 \times 10^{-9}$	$0{\cdot}048_2$	...
50	$1{\cdot}3_2 \times 10^{-6}$*	...	$0{\cdot}004_8$	...
20	$3{\cdot}2 \times 10^{-7}$*	$1{\cdot}9 \times 10^{-11}$	$0{\cdot}001_2$	...
−78	$5{\cdot}8 \times 10^{-8}$*	...	...	...

*Calculated from direct experiment

Where:

$$U = \frac{T - T_2}{T_1 - T_2}$$

$$\tau = \frac{a^2}{b^2} \cdot t \qquad \text{with } b = \text{radius of cylinder}$$

r = distance from axis

$$R = \frac{r}{b} \qquad t = \text{time from start of heating or cooling}$$

T = variable temperature required

T_1 = initial temperature of body

$$M = \mu b$$

T_2 = constant temperature of surroundings

$$H = hb$$

k = thermal conductivity

ρ = density

$$a^2 = \frac{k}{S\rho}$$

S = specific heat

a^2 = thermal diffusivity

h = heat transferred/cm²/s/° C from body to cooling medium/thermal conductivity of the body

and M has all values satisfying:

$$HJ_0(M) = J_1(M) \quad \ldots\ldots(8)$$

and

$$A_n = \frac{2H}{(H^2 + M_n^2) \cdot J_0(M_n)} \quad \ldots\ldots(9)$$

J_0 = Bessel function of first kind and zero order.

J_1 = Bessel function of first kind and first order.

The numerical values for the solution of the differential equation are tabulated for certain chosen conditions. One set of tables lists values of the fractional temperature change U at various positions between the axis and surface of infinite cylinders at a number of values of time function τ, which is a term including the thermal diffusivity, true time, and dimensions of the body. A further variable is the factor h, which is the ratio of surface heat transfer coefficient

TABLE II(*a*)
Calculation of radial gradient in finite cylinder

Radial distance from axis, x/r	0	0·5	0·6	0·7	0·8	0·9	1·0
Residual fraction for infinite cylinder	0·699	0·556	0·497	0·430	0·357	0·279	0·200
Residual fraction at centre of infinite plate of thickness, $2l$	0·878	...	...	...	...	...	...
Residual fraction on radius at mid-length of cylinder, $2r = 2l$	0·614	0·488	0·436	0·378	0·313	0·245	0·176

TABLE II(*b*)
Calculation of axial gradient in finite cylinder

Axial distance from mid-thickness $= x/l$	0	0·5	0·6	0·7	0·8	0·9	1·0
Residual fraction for infinite plate	0·878	0·725	0·658	0·578	0·488	0·388	0·279
Residual fraction at axis of infinite cylinder of diameter $= 2r$	0·699	...	...	...	...	...	...
Residual fraction on axis of finite cylinder, $2r = 2l$	0·614	0·507	0·460	0·404	0·341	0·271	0·195

TABLE II(*c*)
Calculation of axial gradient in cylinders ($L = 2D$) where $\tau_R = 0{\cdot}12$ and $H_R = 4$

Axial distance, diameters from centre	0	0·5	0·6	0·7	0·8	0·9	1·0
$U - \infty$ plate: $\tau = 0{\cdot}03$, $H = 8$	0·999	0·979	0·951	0·891	0·780	0·601	0·350
$U - \infty$ cylinder: $\tau = 0{\cdot}12$, $H = 4$	0·889	...	...	...	...	...	...
Axial gradient, cylinder, $L = 2D$	0·888	0·870	0·845	0·792	0·693	0·534	0·311

to thermal conductivity of the cylinder. A second set of tables give similar calculated results for plates of finite thickness, but of infinite area.

Analogues of heat flow for hydrogen diffusion calculations

In using the heat flow equations for calculation of hydrogen diffusion it is necessary to use the following pairs of constants for analogous calculations.

Heat flow	Hydrogen diffusion
T = Temperature	H = Hydrogen concentration
S = Specific heat	S = Hydrogen solubility
K = Thermal conductivity	P = Hydrogen permeability
$a^2 = K/S$ = Thermal diffusivity	K = Hydrogen diffusivity
ρ = Density, t = Time (in seconds)	common to both systems.

The values for hydrogen solubility used in calculating the diffusion constant given in Table I were expressed in absolute units, (i.e. cm³ hydrogen/cm³ steel) whereas the unit in most common use in the UK is ml/100 g. Fortunately it is not necessary to transform all the units for the purpose of calculation because in the practical case it is the ratio of hydrogen remaining to the initial content which is required; i.e. a dimensionless ratio U, given by:

$$U = \frac{\text{Initial hydrogen} - \text{hydrogen lost}}{\text{Initial hydrogen} - \text{final equilibrium hydrogen}} \quad (10)$$

Usually the final equilibrium hydrogen content would be zero, so that the ratio reduces to:

$$U = \frac{\text{Final hydrogen content}}{\text{Initial hydrogen content}} \quad (11)$$

and this use of U for the residual hydrogen fraction is analogous to the same ratio in terms of temperature in the heat flow problem.

If other variables are kept constant, the time required to reach a given heat or hydrogen distribution will be proportional to the square of the dimension of the body, and in the tables Russell reduces the number of variables by putting:

$$\text{Time function } \tau = \frac{\text{Thermal diffusivity} \times \text{time}}{(\text{cylinder radius})^2} \quad (12)$$

The same substitution in hydrogen analogue calculations gives:

$$\tau = \frac{\text{Hydrogen diffusivity} \times \text{time}}{(\text{cylinder radius})^2} = \frac{kt}{b^2} \quad (13)$$

and this step simplifies the calculation for diffusion in a mass of steel undergoing a forging or annealing cycle where both physical dimensions and temperature (and hence diffusion constant) may be varying independently. It is often convenient to calculate the time function τ as the sum of a number of individual steps each relating to one operation:

$$\tau = \frac{k_1 t_1}{b_1^2} + \frac{k_2 t_2}{b_2^2} + \cdots \frac{k_n t_n}{bn^2} \quad (14)$$

In some circumstances, for instance in annealing cycles, the dimensions remain constant and it may be more convenient to rearrange the summation to the form:

$$\tau = \frac{1}{b^2}(k_1 t_1 + k_2 t_2 + \cdots k_n t_n) \quad (15)$$

and in other cases, for example in forging operations, an approximate result can be calculated by assuming a mean temperature and summing the series for τ in terms of times spent at various dimensions:

$$\tau = K\left(\frac{t_1}{b_1^2} + \frac{t_2}{b_2^2} + \cdots \frac{tn}{b_n^2}\right) \quad (16)$$

CALCULATION OF END EFFECT IN FINITE CYLINDERS

Calculation of rates of diffusion in cylindrical forgings are frequently required, and in the case of cylinders of high length/diameter ratio the use of Russell's tables calculated for an infinitely long cylinder is satisfactory. In the case of short cylinders a correction for end losses may be required; Russell has suggested how this correction may be calculated by considering a finite cylinder as a combination of an infinite plate of thickness equal to the length of the cylinder, and an infinite cylinder of the required diameter.

Russell's method is graphical, involving plotting thermal gradients in three axes mutually at right angles, followed by multiplication to find the required result at a selected coordinate within a finite symmetrical body. It is often simpler for the purposes of hydrogen calculation to work directly from the tables, obtaining any missing values by interpolation.

In the tables Russell gives results for the solution of the heat flow problem with a number of different boundary conditions. The factor H is used to connect the heat conductivity in the solid to the thermal diffusivity at the interface of solid and quenching medium. In the hydrogen analogue this is equivalent to a relationship between internal diffusion and escape at the surface to the external atmosphere. The hydrogen concentration in the latter is usually zero, and if instantaneous equilibrium between hydrogen reaching the surface and hydrogen escaping is assumed, then the factor $H=\infty$ would give the required analogue table. In practice this instantaneous equilibrium is not usually obtained, and the appropriate factor has been found by the comparison of theory with experimental results given in a later section.

Considering the case of diffusion from a finite cylinder of radius $2r$ and length $2l$ the proposed method of calculation of internal hydrogen concentrations at time interval t from the start is illustrated in the following example.

Diffusion in a finite cylinder with delayed surface desorption

Considering the cylinder as a portion of an infinite cylinder of radius $2r$, the time function τ_R for radial diffusion is given by $\tau_R = kt/r^2$ where k and t are the appropriate diffusion constant and time respectively.

Alternatively, if the finite cylinder is considered as part of a normal section of an infinite plate of thickness $2l$, then the axial time function τ_A is given by $\tau_A = kt/l^2$. It is evident that for a cylinder of equal length and diameter the time function τ has the same value both axially and radially, but in all other cases the values of τ_A and τ_R will differ.

For example, for a cylinder of equal length and diameter at time function $\tau = 0{\cdot}2$ and surface factor $H = 4$ the steps in calculating the radial and axial gradients are shown in Tables II (a) and (b) respectively. It will be seen by comparison of corresponding points on the axis and mid-length diameter that the gradients vary by a maximum of 10%, the radial fall being rather more rapid than the axial. The relatively short length of the cylinder also causes the maximum residual fraction, at the centre, to be about 15% less than the axial concentration in an infinitely long cylinder of the same diameter.

TABLE III

Calculation of hydrogen diffusion during an annealing cycle

Operation	Temp., °C	Time, h	kt h	kt
Equalize at	700	4*	0·792	3·2
Soak at	700	10	0·842	8·4
Heat to	900	20	0·705	14·1
Soak at	900	10	0·313	3·1
Cool to	720	18	0·367	6·6
Soak at	720	10	0·867	8·7
Heat to	900	18	0·689	12·4
Soak at	900	10	0·313	3·1
Cool to	720	18	0·367	6·6
Soak at	720	10	0·867	8·7
Cool to	700	2	0·854	1·7
Soak at	700	24†	0·842	20·2
Cool to	150	55	0·511	28·1
Air cool	RT	...	...	0·6
				kt = 125·5

* Assumes forging received hot at 600° C
† May be extended as required for hydrogen diffusion

Calculation for cylinders of other length/diameter ratios

The case chosen in the preceding example was simplified by the fact that the time function had the same value on both axes, but this is not true for other length/diameter ratios. For example, if the cylinder has a length equal to two diameters, then the semi-axis is twice the radius and τ_A will be one-quarter the value of τ_R, since τ depends on the inverse square of the dimension. For a cylinder whose length is twice its diameter for $\tau_{\text{cylinder}} = 0{\cdot}2$, the value of τ_{plate} used must be $\tau = 0{\cdot}05$. The calculation then follows the principle of the earlier example.

In Fig. 1, the radial and axial distributions in cylinders of different length/diameter ratio are compared for four values of time function τ. It will be seen that the radial distribution is substantially that of an infinite cylinder in transverse planes at more than one diameter from an exposed end. The end gradient is not seriously affected until the length of the cylinder becomes less than two diameters. In order to simplify the preceding discussion the effect of the surface transfer factor H was omitted; it did not affect the numerical example, being the same in radial and axial directions, but it was taken into account in the calculations leading to the diagrams of Fig. 1.

It is clear that the same method of calculation, starting from the tables for infinite plates can be used to calculate the distribution in infinite blocks of rectangular cross-section and also for finite rect-

angular blocks, by considering these as cases of the intersection of two or three infinite plates respectively.

Effect of dimensions on surface transfer factor *H*

Reference to Russell's paper shows that a mathematical transformation, putting $H = hL$ was made to simplify the solution of the Bessel functions, and there h was given by:

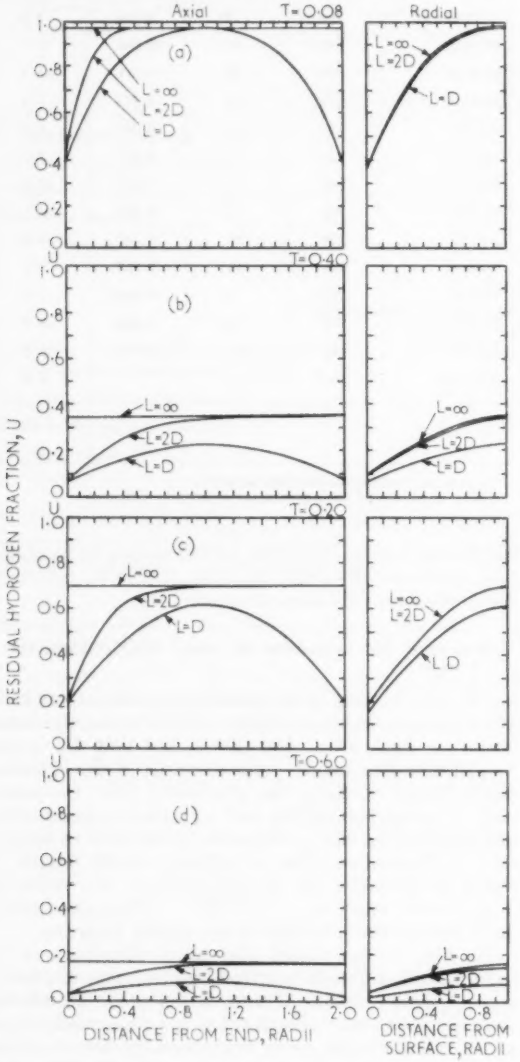
$$h = \frac{C}{k}$$ where C = Newton's constant of proportionality
k = Thermal conductivity
L = Cylinder radius

In the hydrogen analogue, k is hydrogen permeability; if the analogy is to be preserved it seems that the value of H should change with the dimension of the cylinder or plate in which diffusion occurs, and it follows that the values of surface factor H will differ in radial and axial directions in a finite cylinder unless length is equal to diameter.

For example, in a cylinder of length equal to two diameters (a practical case considered later) at a value of radial time function $\tau_R = 0{\cdot}12$, the axial time function will be $\tau_A = 0{\cdot}03$. Since the surface factor H is proportional to dimensions if $H = 4$ is correct for radial diffusion, the axial surface factor will be $H = 8$. Therefore, in calculating an axial gradient for hydrogen concentration in a finite cylinder the following values are required from the tables:

(i) radially $\tau = 0{\cdot}12$, $H = 4$
(ii) axially $\tau = 0{\cdot}03$, $H = 8$.

These calculations are summarized in Table II (*c*) The shape of the axial hydrogen distribution curve is very much altered by the value chosen for H and Fig. 2 shows graphically the results of calculations of the hydrogen gradient for various values of surface factor H, but all for cylinders of length equal to two diameters (or the nearest pair of values obtainable from the tables) at radial time function $\tau_R = 0{\cdot}12$, using the method outlined above.



τ cylinder		0·08	0·20	0·40	0·60
	τ plate	0	0	0	0
L = ∞					
	H ,,	∞	∞	∞	∞
	τ plate	0·02	0·05	0·10	0·15
L = 2D					
	H ,,	8	8	8	8
	τ plate	0·08	0·20	0·40	0·60
L = D					
	H ,,	4	4	4	4

H cylinder is 4 in all cases

Fig. 1—Diagrams showing hydrogen gradients on axis and mid-length radius of cylinders at three length/diameter ratios and four values of time function

CALCULATION OF HYDROGEN DIFFUSION DURING ANNEALING CYCLES

In calculating the hydrogen diffusion occurring during annealing cycles it is convenient to consider the programme as a series of periods at steady temperatures, alternating with periods of steady rise or fall of temperature. In the case of large forgings these changes do approximate to the linear changes planned, and since the forging will tend to lag on both heating and cooling the errors will tend to cancel each other. When considering air cooling of large masses, or pit cooling of billets it may be necessary to divide the cooling period into portions from a determined cooling curve and obtain the total by summation.

Since at temperatures above 200° C the diffusion constant is roughly proportional to temperature (° C) the heating or cooling period may be calculated at the *mean* temperature. Similar approximations can be made for diffusion in γ-iron if required. The case of $\alpha \rightarrow \gamma$ transformations can be solved graphically to find a mean constant for diffusion over the required temperature range, but for most purposes it is sufficiently accurate to assume the steel to be ferritic to the mid-point of the transformation range and austenitic at higher temperatures, dividing the time cycle in the appropriate ratio.

A typical calculation for an annealing cycle is shown in Table III, giving a value of $\Sigma kt = 126$ approx. Using the annealing cycle with a long cylindrical forging of 20 in. dia.:

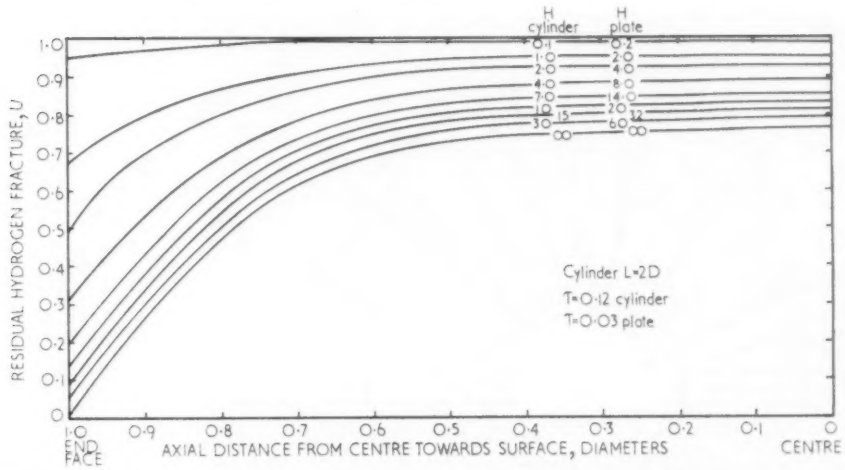


Fig. 2—Theoretical diffusion gradients on axis of a finite cylinder showing effect of surface reactivity

$$r = 25{\cdot}4 \text{ cm}$$
$$r^2 = 645$$
$$\text{and } \tau = \frac{\Sigma kt}{r^2} = \frac{125}{645} = 0{\cdot}194$$

Reference to the appropriate table (Cylinder, $H = 4$) shows the corresponding value for the remaining hydrogen fraction U at the axis to be 0·714.

For a shorter cylinder it would be necessary to calculate the axial diffusion also, and to apply the appropriate correction.

CALCULATION OF HYDROGEN DIFFUSION DURING FORGING CYCLES

Calculation of hydrogen diffusion during forging operations and the intermediate high-temperature reheating and soaking periods is more difficult than for annealing, not only because there are rapid temperature changes during forging and hence severe temperature and diffusivity gradients, but also because the physical size of the mass of steel is varied at each operation. It is therefore necessary to make some assumptions to obtain an approximate result. In the calculations the time at each stage is taken as the period between half-way through a given forging operation and half-way through the next. The effect of temperatures may be dealt with in two alternative ways. In the first, approximate, method the forging is assumed to be at a temperature of 130° C below the soaking temperature for the whole of the forging period. This is partly based on surface temperature measurements and on observations on interior temperatures during parting-off discards, etc. and partly by comparison with the more detailed calculation by the second method. In the latter the results of a series of readings are used to plot a time/temperature graph and the times spent by the forging

TABLE IV

Comparison of approximate, graphical, and planimeter methods for calculation of time function τ in forging operations

	(*a*) Approximate method				(*b*) Planimeter method			(*c*) Time–temperature method	
Stage	Dia., in.	r^2, cm^2	Time, s × 10^{-3}	t/r^2	Planimeter reading	Equivalent kt	τ	Calculated kt	τ
Cast—Opn. 1	38·5	2393	107·5	44·9	0·672	23·1	0·0097	24·0	0·0105
Opn. 1–2	35	1980	222·4	112·3	1·204	41·4	0·0209	43·6	0·0220
2–3	49·5	3953	72·0	18·2	0·465	16·1	0·0041	16·2	0·0041
3–5	40	2582	108·9	42·2	0·703	24·2	0·0094	24·2	0·0094
5–7	37·5	2276	90·9	39·9	0·562	19·5	0·0086	20·1	0·0088
7—Anneal	36	2090	3·6	1·7	0·017	0·6	0·0003	0·8	0·0004
				$t/r^2 = 259{\cdot}2$					
Mean diffusion constant = 1·96 × 10^{-4} $\tau = k\Sigma t/r^2 = 259{\cdot}2 \times 1{\cdot}96 \times 10^{-4}$ $\tau = 0{\cdot}0508$ approx.					$\tau = 0{\cdot}0530$			$\tau = 0{\cdot}0552$	

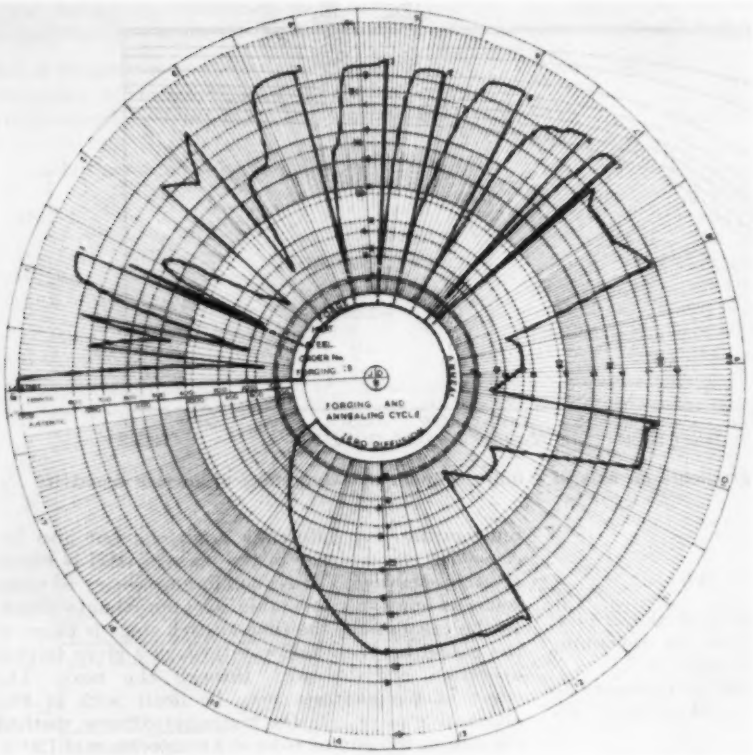


Fig. 3—Circular chart for hydrogen diffusion calculations. Original diameter 15·4 in., calibration of planimeter: 1 rev. = 2·5 linear inches ≡ Σkt 34·4

at each diameter in temperature ranges 100° C wide are separately estimated. From these results a value of $\Sigma kt/r^2$ can be obtained by summation. This method is made easier by the use of a special graph paper in the form of a circular chart in which time is represented by angular rotation and diffusion rate by displacement radially outwards (Fig. 3). Two concentric scales are provided, for diffusion in α- and γ-iron respectively, so that transformations can be represented. After tracing the appropriate time/temperature cycle on the chart, the area (which is proportional to Σkt) can be readily obtained by measurement of the area enclosed between the periphery of the temperature graph and the zero circle with a planimeter used as a radial-arm instrument rotating about the centre of the chart. For the chart illustrated the conversion factor is given by:

$$\Sigma kt = 34{\cdot}4 \times \text{change in planimeter reading.}$$

The annealing cycle corresponding to Table III is plotted, together with a forging cycle. Table IV(a) shows the application of the approximate calculation to a forging cycle; Table IV(b) gives the planimeter readings from Fig. 3; Table IV(c) summarizes a long time-temperature-radius calculation. Comparison of the value of τ obtained by the three methods shows good agreement, and because the forging cycle usually contributes only a small fraction to the total diffusion, the approximate method usually suffices for routine use.

The planimeter diffusion chart of Fig. 3 also shows the annealing cycle calculated in Table III in graphical form. The planimeter reading obtained from the chart was 3·676, which when multiplied by the chart conversion factor of 34·4 gives $\Sigma kt = 126{\cdot}4$ for the annealing cycle, compared with 125·5 by calculation. Table V gives further examples of the results of time-function (τ) calculation made by the methods described. The rather large disagreement between approximate and planimeter methods for forging 9 is due to the fact that a week-end interrupted the

TABLE V

Comparison of τ calculated by various methods

Forging	Value of time function τ calculated for:				
	Forging cycle			Annealing cycle	
	Approx. method	Planimeter method	Time–temp. method	Calculation	Planimeter
5	0·0508	0·0530	0·0552	0·0596	0·0605
7	0·0491	...	0·0517	...	...
8	0·0544	0·0524	...	...	...
9	0·0544	0·0410	...	...	...
B	0·0391	0·0336	...	0·592	0·580

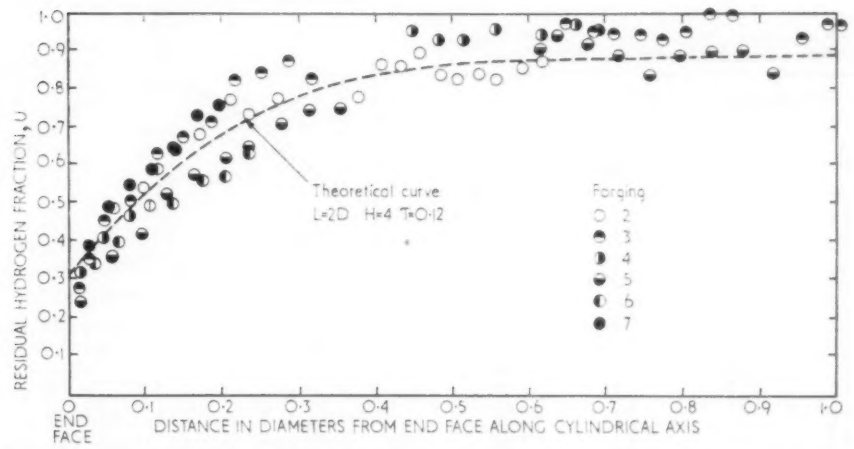


Fig. 4—Comparison of hydrogen results on cores from bottom-end discards from six large rotor forgings with calculated gradient

forging cycle, invalidating the assumption for the mean forging temperature.

DEDUCTION OF VALUE OF SURFACE FACTOR *H* FROM EXPERIMENTAL RESULTS

As pointed out in an earlier section, the choice of value of surface factor H has a large effect on the axial hydrogen gradient at the end of a finite cylinder. During the course of a series of experiments on hydrogen diffusion in large forgings, discards of about 20 in. dia. were obtained from six forgings in 3%Cr–Mo steel. In each case core-pieces of about 1 in. dia. trepanned from the axis of the discard were analysed for hydrogen content. The discards had a mean diameter of $20\frac{3}{4}$ in. (range $18\frac{1}{2}$–$23\frac{1}{2}$ in.) and the average value calculated for time function τ was 0·119 (range 0·103–0·139). The initial hydrogen content based on notched-pencil tests cast from metal from the ladle varied between 3·9 and 5·6 ml/100 g.

Direct comparison between the six discards is possible if the hydrogen content found in the discard core-pieces is expressed as a fraction U of the original hydrogen content, and its position in terms of diameters from the exposed end, time function τ being taken at the mean value of 0·12. When plotted in this way the experimental results give Fig. 4, from which it will be seen that the points fall in a band showing a definite end gradient. Comparison with the theoretical curves plotted in Fig. 2 enables the surface factor $H = 4$ to be chosen to give most satisfactory agreement between theory and practice. The form of the curve shows that the diffusion process does not reach instantaneous equilibrium at the surface of the forging, leading to the deduction that in practical cases the rate of hydrogen loss will be considerably slower than the rate predicted from theoretical calculations based on measurements of diffusion constants made under laboratory conditions

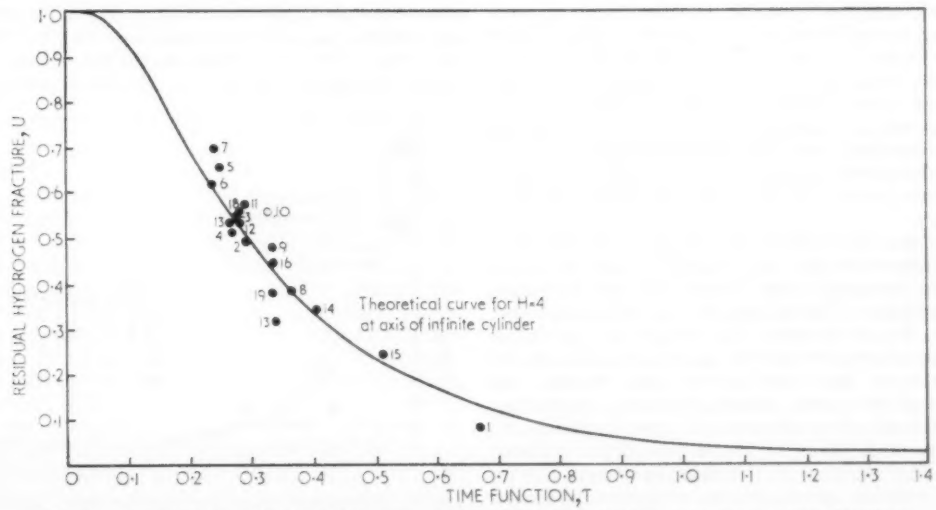


Fig. 5—Comparison of theoretical curve and observed hydrogen loss from rotor forgings

TABLE VI

Comparison of hydrogen results on 3%Cr–Mo steel forgings with value predicted by calculation

Forging*	Hydrogen content, ml/100 g			Calculated time function, τ
	In ingot†	In trepanned axial core	Predicted by calculation	
1	9·0	0·7$_5$	0·7	0·670
2	5·9	2·9	2·9$_5$	0·294
3	5·2	2·8$_5$	2·8	0·279
4	4·7	2·4	2·5$_5$	0·272
5	4·0	2·6	2·3$_5$	0·253
6	4·7	2·9	2·8$_5$	0·241
7	4·3	3·0	2·6	0·244
8	6·2	2·4	2·3$_5$	0·368
9	4·8	2·3	2·0	0·339
10	4·7	2·6	2·2	0·330
11	4·3	2·4$_5$	2·2	0·290
12	3·6	1·9$_5$	2·1	0·282
13‡	4·9	1·5$_5$ 2·6$_5$	2·1 2·7	0·338 0·267
14	6·8	2·3	2·1	0·405
15	5·0	1·2$_5$	1·1$_5$	0·509
16	4·9	2·2	2·1	0·335
18	4·2	2·3$_5$	2·2$_5$	0·277
19	5·3	2·0$_5$	2·2	0·329

* Forging diameters 24–43 in.
† Initial hydrogen content based on determinations on liquid steel in furnace before tap, from ladle, and on core-piece trepanned from forging discard
‡ Forging with two barrel diameters

with uncontaminated surfaces and non-rate-determining surface reactions.

RESULTS OBTAINED ON LARGE FORGINGS

Using the methods described in earlier sections the annealing required for 18 forgings with diameters ranging from 24 to 43 in. were calculated and applied. All these forgings were made from 3% Cr–Mo steel. The hydrogen content of the original ingot was known from notched-pencil samples taken from the liquid steel from the ladle, and from the furnace before tapping, and in most cases a core-piece trepanned from a forging discard was used to confirm the results obtained on the notched-pencil test-pieces.

In Table VI the results predicted by calculation are compared with the hydrogen content found in test-pieces trepanned from the axis of the forging after heat-treatment. A plot of residual hydrogen fraction U against time function τ is compared with the theoretical curve in Fig. 5. Some scatter is to be expected owing to approximations in calculations and error in analysis, but the measured hydrogen loss shows reasonable agreement with the theoretical curve over quite a large range of values of time function τ.

During the examination of a large 3%Cr–Mo steel rotor a transverse slice was obtained, and test-pieces cut from diametral bars were used for hydrogen determinations. The forging had a trepanned bore, and from Fig. 6, in which the results are presented diagrammatically, it will be seen that although no heat-treatment had been given after boring, the period of three months elapsing between trepanning and sectioning for analysis had been sufficient to allow a marked loss of hydrogen to a depth of about 1½ in. The theoretical distribution curve for an infinite cylinder also predicts a higher hydrogen content at the surface than is actually observed; the

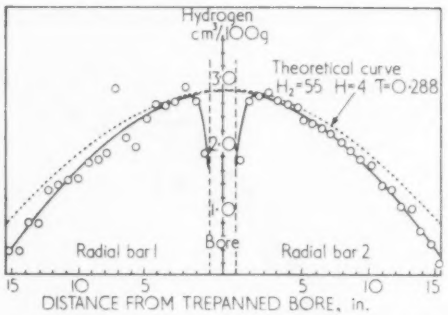


Fig. 6—Hydrogen distribution in radial bars machined from main barrel of rotor forging

discrepancy is probably due partly to surface losses at RT and also to end losses neglected in the calculation. Hydrogen determinations on specimens cut from the 14-in. dia. journals of two similar rotors gave results of 0·1–0·2 ml/100 g; approximate calculations indicate a theoretical result of about 0·15 ml/100 g.

A series of experiments on the cooling of billets rolled from six 14-in. ingots of 1¾%Ni–Mo steel was carried out. Billets ranging from 3 in. to 8 in. square were produced and cooled under a variety of conditions. Hydrogen determinations were made on slices cut from each billet for comparison with values calculated for the cooling cycles applied. Unfortunately the transverse hydrogen distribution showed a marked peak due to segregation near the axis, instead of the smooth theoretical curve. Axial segregation of hydrogen is often found in square billets, but many cases have been found where the distribution is near the theoretical. The ingots also appear to have been of variable hydrogen content, falling roughly into groups with hydrogen about 5·6 or 7·7 ml/100 g, leading to scatter in the results. In spite of these difficulties it will be seen from Fig. 7 that the observed hydrogen content follows the relationship with time function τ reasonably well over a wide range of experimental conditions, with rapid air cooling as one extreme and a furnace anneal lasting 6–7 days as the other. The theoretical curves are calculated for square-section billets of 7-in. thickness and infinite

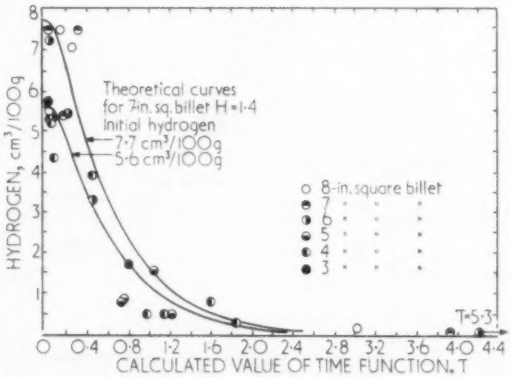


Fig. 7—Relationship between time function τ and hydrogen remaining at axis of billets

TABLE VII

Effect of initial hydrogen content on duration of 'safety' diffusion annealing for hydrogen removal

Hydrogen in liquid steel, ml/100 g	Fraction U at 2 ml 100 g	Corresponding time function, τ	τ with 0·05 deducted for forging	Equivalent kt	Deduct $kt = 126$ for basic anneal	Extra time at 700° C required, h	Final hydrogen content after basic anneal
8·0	0·250	0·488	0·438	282	156	185	4·75
7·0	0·286	0·452	0·402	259	133	158	4·16
6·0	0·333	0·408	0·358	231	105	125	3·56
5·0	0·400	0·356	0·306	197	71	84	2·97
4·0	0·500	0·296	0·246	159	35	42	2·38
3·0	0·667	0·214	0·164	106	...	Nil	1·78

Assumptions: Forging diameter = 20 in. $r^2 = 645$; Surface factor $H = 4$; Forging losses equivalent to $\tau = 0·05$; At 700° C, kt h = 0·842. Basic annealing cycle as given in Table III, $kt = 126$

length, using the plate diffusion tables with the surface factor $H = 1·4$.

FAILURES OF LARGE ROTOR FORGINGS

There have been at least four failures of large rotor forgings in the USA recently.[6-9] In one case hydrogen was the main cause of failure; it was a contributory factor in two others. In the case of the Arizona rotor, a paper by Shabtach *et al.*[6] gives sufficient information for an approximate calculation of hydrogen diffusion losses to be made. The 95-ton basic OH steel ingot was given a 340-h treatment before forging, and 540 h afterwards, with a total of 1290 h before reaching RT. In spite of this very long period during which hydrogen diffusion could occur, it is calculated that starting from a typical basic OH steel hydrogen content of 5·5 ml/100g, at least 3·7 ml/100g would remain at the axis. Retempering and stress relief would be expected to leave 3·0–3·2 ml/100g hydrogen near the bore. The paper quotes values of 2·8–3·2 ppm (i.e. 3·1–3·6 ml/100g) for positions 3–6 in. from the bore, so it seems that the assumptions necessarily made in the calculations are valid, and the method can be applied to the heaviest forgings used for rotors in generators and turbines.

In the case of the Ridgeland turbine spindle,[7,9] where failure was entirely attributed to flaws produced by hydrogen, considerably fewer data are available for calculation, but a rough estimate suggests that four months at 650° C additional to the total heat-treatment used would be required to halve the hydrogen content of a forging of that size. The hydrogen content of 1·1 ml/100g quoted for a single determination is very low for so large a forging, and it seems likely that either hydrogen was lost in sampling or that the specimen came from a position near a free surface. The Tanners Creek rotor[8] had 0·5 ml/100g in the shaft extension before service, and 0·1 ml/100g in a 'wheel' after failure. A theoretical calculation shows that the 22 months of service operation at 500° C would be sufficient to remove all but a trace of hydrogen from the main rotor body, and the hydrogen content of a wheel would be expected to be extremely low. The Cromby rotor,[6] where hydrogen embrittlement was thought to be a secondary cause of failure, contained 1·1–2·2 ml/100g compared with an approximate calculated value of ~3 ml/100g. Some losses may have occurred during machining and service for which no allowance has been made.

APPLICATION OF DIFFUSION THEORY IN WORKS INVESTIGATIONS

Theoretical calculations may be of use in the investigation of some cases of hairline cracking encountered in forgings where safety heat-treatment or routine annealing at first sight seems adequate, and four interesting cases are briefly discussed in the following paragraphs.

A 24-in. dia. shaft forged from 2¾%Ni–Cr–Mo steel was found to contain many cracks during ultrasonic testing, and hydrogen determinations showed 3·7 ml/100g to be present at the axis. It was calculated that after annealing the hydrogen content was roughly 4·3 ml/100 g, and that the liquid steel had a hydrogen content of about 5·2 ml/100 g. Thus the original hydrogen was not excessive, but the annealing treatment had not been of sufficient duration to lower the residual hydrogen to a safe level.

A shaft of only 5 in. dia. made from 4¼%Ni–Cr–Mo steel was found to show severe hairline cracking during machining, but hydrogen determinations gave less than 0·2 ml/100 g. A calculation on the annealing cycle predicted less than 1% of original hydrogen content in the annealed forging. Investigation into works records showed that because of an accident the forging had been at RT for five days when only partly forged, and the residual hydrogen was estimated at 85% at that stage. It was therefore fairly clear that the cracks had developed in the interval between forging operations, when the hydrogen content would not be much reduced from the original level, and the damage had already occurred before the safety anneal was applied.

A rather similar occurrence on a much larger scale was found during the examination of a 37-in. dia. forging which contained very large cracks. The records showed forging to have been carried out in two sessions separated by about six weeks, each followed by an anneal. Calculation showed that

after the first anneal about 95% of the original hydrogen would remain at the axis, whereas after the second anneal the calculation indicated 64% remaining. It was deduced that the forging had developed hairline cracks after the first anneal, and these cracks had been enlarged by the second series of forging operations.

In the case of a forging of 23 in. dia. made from a 5-ton ingot of Ni–Cr–Mo steel where hairline cracks were found, a puzzling feature was the absence of defects in a similar forging of 16 in. dia. made from part of a 7½-ton ingot from the same heat of steel. During the investigation it was found that a furnace breakdown, when the ingots had been forged to 24 in. and 26 in. dia. respectively, had resulted in the forgings falling to ambient temperature for several days. By calculation it was deduced that 98% of the original hydrogen remained at this stage, and it seems likely that both forgings developed flaws. In the case of the larger forging insufficient further work in the flawed zone allowed the defects to persist in the final stages and hence the subsequent anneal which would remove hydrogen down to 45% of the original value would be ineffective. In the case of the smaller forging, the later reduction from 26 in. to 16 in. dia. was thought to have welded any defects, and the subsequent annealing lowering the hydrogen to 18% of the original value would leave the forging in a flaw-free condition.

Using similar calculations it is often possible to estimate the probability of obtaining a useful hydrogen result before the expense of large-scale machining operations is undertaken in course of works investigations, and in such cases the absence of hydrogen determinations on the original liquid steel does not prevent useful deductions from being made. For example it is easy to show that the determination of hydrogen in the wheels of gashed rotor forgings is not likely to be informative once a stress-relief heat-treatment has been applied, and similar considerations can also be applied to billets and castings of small cross-section if the approximate thermal history is known.

DISCUSSION

A number of important practical points arise from the form of the theoretical curve linking time function τ with residual fraction U. The appreciable delay before any change in hydrogen content takes place at the axis of a cylinder or plate and their non-linear connection, and the square-law relationship between diffusion and size are usually overlooked. The initial axial delay occurs while a diffusion gradient is being formed between axis and surface, and is increased as the surface conditions become more removed from instantaneous equilibrium. In making large forgings and in rolling ingots the relationships between size, time, and temperature are such that the time factor for these operations is of the order of $\tau = 0{\cdot}05$, and in these circumstances, although appreciable losses occur from surface layers, there is virtually no loss of hydrogen at the axis. It follows that a comparison of hydrogen determinations on the liquid steel with results on test-pieces trepanned from near the axis immediately after forging or rolling requires very little correction of the latter results for diffusion loss, and hence gives a very useful check on the notched-pencil tests obtained during steelmaking.

Another aspect which requires stressing is the saving in 'safety' heat-treatments obtainable from reductions in the hydrogen content of the liquid steel. This can be seen from an inspection of Table VII, which summarizes the results of calculations for the annealing cycles required to reduce the hydrogen content at the axis of a 20-in. dia. forging to 2 ml/100g starting from 3–7 ml/100g in the liquid steel, and assuming diffusion equivalent to time function $\tau = 0{\cdot}05$ to be accumulated during the forging operations. Taking the basic annealing cycle of Table III, the table shows the calculated final axial hydrogen content, and also the number of extra hours at 700° C required to reduce the hydrogen content to 2 ml/100g. The basic cycle reduces the hydrogen to the required level with a maximum initial content of 3·37 ml/100g, which is attained only in good acid Siemens steelmaking practice. For basic electric steelmaking, where the normal hydrogen content with careful steelmaking is likely to be 4–5 ml/100g, 40–85 h of extra annealing would be required; if no special precautions were taken the hydrogen content of the liquid steel would probably be 6–7 ml/100g, and the corresponding extra anneal would be of the order of 125–160 h. Reduction of the liquid-steel hydrogen content by careful attention to steelmaking practice can therefore result in a saving on the safety heat-treatment of about 80–90 hours in the example considered. Finally, consideration of the results quoted for the American rotors will show that a safety treatment for removal of hydrogen by diffusion becomes quite impractical for large-diameter forgings, since the annealing times required may easily run into thousands of hours. On the other hand the examination of steam-turbine rotors withdrawn after years of service should show a negligible hydrogen content due to loss by diffusion at working temperature.

ACKNOWLEDGMENTS

The author is grateful to Mr E. W. Colbeck, Metallurgical Director, Hadfields Ltd, for permission to publish this paper. The author also thanks the many colleagues in both works and research department who have assisted by collecting data, obtaining specimens, and making hydrogen analyses.

REFERENCES

1. C. Sykes, H. H. Burton, and C. C. Gegg: *JISI*, 1947, vol. 156, pp. 155–180.
2. A. Sieverts: *Zeitschrifte für Physikalische Chemie*, 1911, vol. 77, p. 591.
3. C. J. Smithells and C. E. Ransley: *Proc. Roy. Soc.*, 1935, vol. 150, ser. A, pp. 172–197.
4. T. F. Russell: 1st Report of the Alloy Steels Research Committee, *ISI. Spec. Rep.* No. 14, pp. 149–187, 1936.
5. J. D. Hobson: *JISI*, 1958, vol. 189, pp. 315–321.
6. C. Shabtach *et al.*: *Trans ASME*, Preprint 55–A–208.
7. H. D. Emmert: *Ibid.*, Preprint 55–A–172.
8. A. W. Rankin and B. R. Seguin: *Ibid.*, Preprint 55–A–210.
9. R. G. Matters *et al.*: *J. Met.*, 1956, vol. 8, Mar., pp. 317–324.

The distortion of high-carbon high-chromium die steel

EFFECT OF VARIATIONS IN CARBIDE DISTRIBUTION ON THE SENSITIVITY OF THE STEEL TO DISTORTION

By K. Sachs, M.Sc., Ph.D., and G. T. F. Jay, B.Sc., A.C.T. (Birm.), A.I.M.

SYNOPSIS

The sensitivity of die steels to distortion on heat-treatment is known to be associated with the macrostructure, particularly the carbide distribution. A study of the effect of forging with hammers of different rating, press forging, and upset forging, has indicated that the main structural features responsible for distortion are the directionality and particle size of the carbides and that variations in forging technique have only a marginal effect on distortion behaviour. The closest approximation to random carbide distribution is obtained in small castings and distortion tests on cast specimens gave comparatively good results. 1530

DIES FOR THE PRODUCTION of electrical sheet stampings must combine extreme dimensional accuracy with high hardness and wear resistance. A die steel containing about 2½%C and 12½%Cr is used; it is oil-hardened after machining and any change in dimensions resulting from heat treatment must be corrected by grinding. Since the grinding operation is slow and expensive it is desirable to reduce the distortion encountered in heat treatment so that a lower grinding allowance can be specified; in any case, some dimensions, such as distances between holes, are very difficult to correct by grinding. The problem of distortion has been studied in some detail in earlier work* and a test has been developed which is believed to be satisfactorily discriminating with regard to the factors considered to be of the greatest importance.

Experiments reported in the previous paper showed that the major factor in the distortion occurring during heat treatment was the difference in the tendency to anisotropic dilatation during thermal cycles and phase transformations between adjacent layers of the billet. The structure of the steel consists of chromium carbide in a matrix of lightly tempered martensite with some residual austenite; forging draws out the carbides into long stringers running in the direction of hot working, but this effect is not always uniform throughout the thickness of the steel. The amount of expansion and contraction is greater in a direction parallel to the carbide stringers than perpendicular to them. If this anisotropy is not uniform throughout the thickness of the steel, one layer may tend to expand or contract more than an adjacent layer and stresses are set up between the layers, leading to distortion.

It was felt that a pointer to any possibility of reducing distortion might be obtained from a study of the distortion behaviour of steels of similar composition and steelmaking history, but differing in carbide distribution and macrostructure as a result of variations in forging technique, or of the use of cast specimens.

Manuscript received on 29th January, 1958.

The authors are at the GKN Group Research Laboratory, Wolverhampton.

High-carbon high-chromium steels are susceptible to heavy segregation. The macrosegregate consists of the last material to solidify, a eutectic mixture of austenite and chromium carbide, which will be found preferentially in certain regions of the ingot, particularly near the core. The extent and location of any such segregate will depend on the rate of freezing, which in turn depends on the size of the ingot, pouring temperature, and mould design. Under these influences the various zones, e.g. chill crystals, columnar crystals, equiaxed grains, and segregate, taper upwards or downwards in the ingot, so that the proportion of the cross-section occupied by any part of the structure is different according to the position in the ingot.

In this steel the macrosegregate cannot be absorbed by diffusion on heating to elevated temperatures, so that after the solidification of the ingot the segregate can only be broken up by mechanical work. Forging will hot-work and recrystallize the austenitic matrix of the steel and draw out the carbides into stringers parallel to the direction of working; the segregated zones will be deformed substantially in the same way as the ingot as a whole but if the conditions of forging tend to work the centre of the ingot more than the outside, the chances of breaking up the segregate are improved.

The depth of penetration of plastic deformation into the billet during forging depends primarily on the ratio between the tool width and the height of the stock†; the rate of deformation and the force applied, i.e. the rating of the forge, have very much less

* K. SACHS: *JISI*, 1958, vol. 189, July, pp. 216–224.

† P. M. COOK: *Ibid.*, 1955, vol. 179, pp. 250–252.

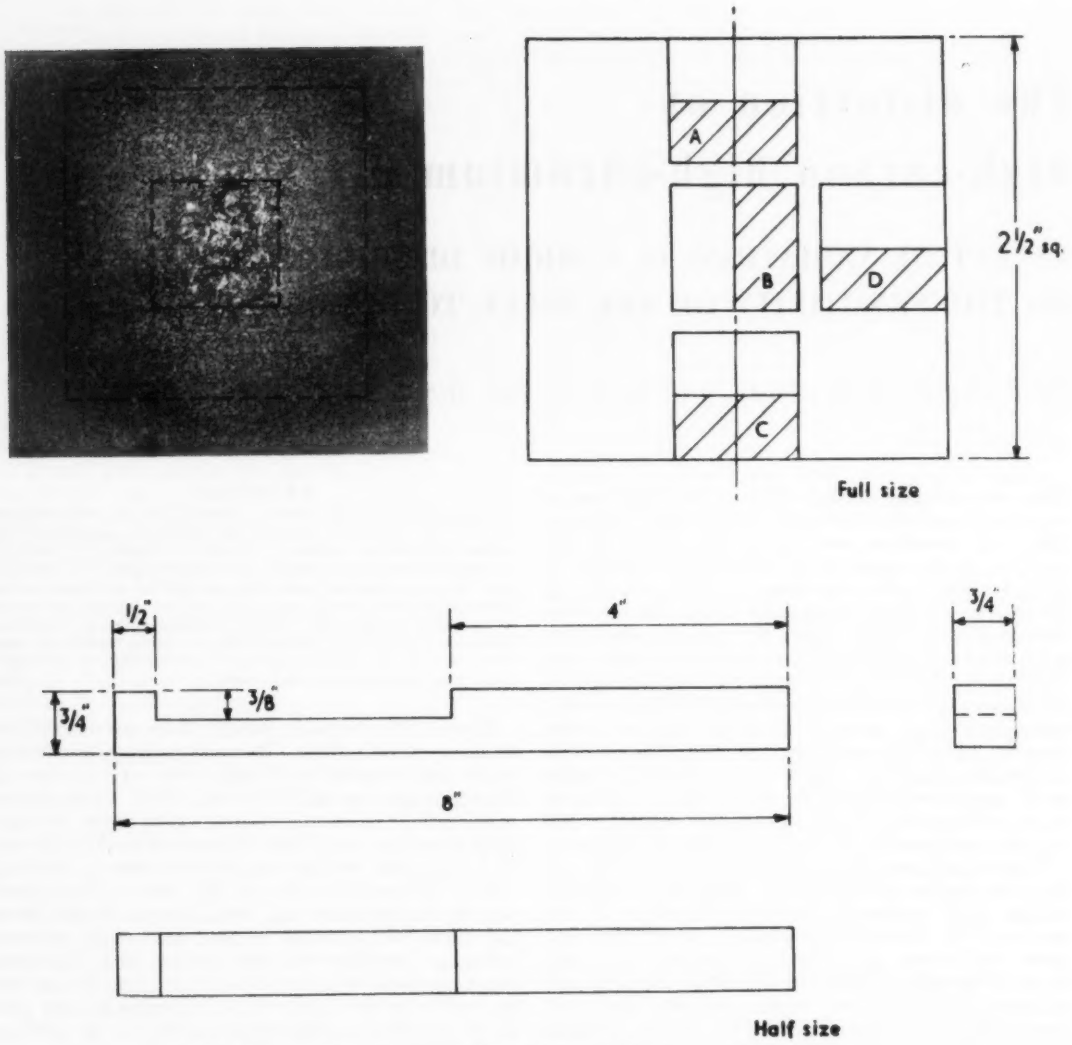


Fig. 1—Distortion specimen and location of specimens in forged bar

influence. It would have been of great interest, therefore, to undertake a systematic study of the effect of forging with tools of different width on the carbide distribution and sensitivity to distortion of the billets. Such experiments involve considerable disruption of production routine in the forging shop; it is more convenient to forge on hammers and presses of different rating with the tools normally employed, fitting the experimental billets into the normal forging programme. This easier path was followed in the first instance and the results obtained led to the abandonment of suggested experiments with different tools in favour of trials with cast specimens.

FORGING AND LABORATORY EXPERIMENTS

Forged billets used for distortion tests

The distortion test developed to reveal the effect of carbide distribution consists of measurements before and after heat-treatment on specimens cut from 2½-in. square billets. The specimens and their disposition in the billet are illustrated in Fig. 1. The macrostructure of the billets shows three distinct zones; specimens 8 in. long and ¾ in. square could be cut from the bar in such a way that the middle one was occupied predominantly by the equiaxed crystals of random orientation, often containing some macrosegregate, while the outer specimens consisted of the outermost and intermediate layers. Half the thickness of the specimen, i.e. one of these layers, was removed over half the length of the specimen, so that a sharp change in section occurred halfway along the specimen. Distortion on heat-treatment occurs partly as a result of this change in section, but mainly because the two adjacent layers of different carbide distribution and dilatation characteristics are pulling against each other. Two specimens from the same bar

TABLE I

Forged billets used for distortion tests

Lab. mark	Ingot section measurements, in.	Forge	Rating, tons	Billet section measurements, in.	Remarks
AAK	5 × 5	Hammer	1	2½ × 2½	
ADB (A)	5 × 5	,,	1	2½ × 2½	
ADB (B)	5 × 5	,,	2½	2½ × 2½	
ADX (A)	5 × 5	,,	3½	2½ × 2½	Bottom of ingot
ADX (B)	5 × 5	,,	3½	2½ × 2½	Top of ingot
ADW (A)	5 × 5	Press	600	2½ × 2½	Bottom of ingot
ADW (B)	5 × 5	,,	600	2½ × 2½	Top of ingot
AFQ (Forged billet) (*ADB* (B))		Hammer	3½	2½ × 2½	Upset to square slab, 2½ in. thick, then forged sideways to bar, 2½ in. square
ACN	24 × 24	Press	900 (?)	2 × 1	Commercial sample

in which the thin section consists of the outer and intermediate layers respectively distort by roughly equal amounts in opposite directions.

For the distortion test the specimens are annealed and then ground flat on opposite surfaces of the thick and thin sections; to facilitate grinding a small projection is left on the end of the thin section. The specimens are hardened, usually in a neutral salt bath, at 960° C, oil-quenched, tempered for one hour at 200° C, and are then measured. The short face of the thick section is supported on a parallel resting on a marking-out slab. A dial gauge mounted on a vernier height gauge is located on the top surface at the thick end, and adjusted to read zero. A dial gauge reading is taken at the middle of the specimen, where the section changes, and the mean of this and the reading at the end (the zero) is regarded as the base line. The difference between this mean and a reading at the thin end serves as the index of distortion. The measurements are carried out on two longitudinal lines

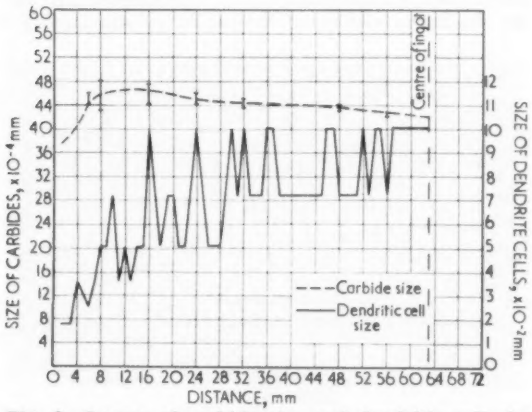


Fig. 2—Survey of carbide size and dendritic cell size from surface to centre of cast ingot *ADX*

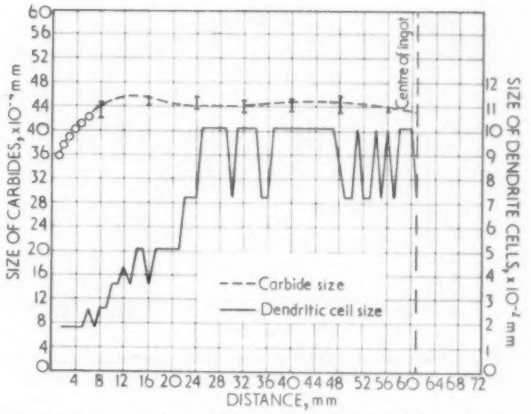


Fig. 3—Survey of carbide size and dendritic cell size from surface to centre of cast ingot *ADW*

on the specimen, not far from the sides, and averaged to allow for slight differences in level due to surface irregularities. The mean distortion index is quoted in the tables. The purpose of the present work was to study the effect of different forging techniques on the macrostructure and the response to this distortion test.

Details of the different forging methods employed are listed in Table I. The bulk of the work was done on 5-in. square ingots. Half of one ingot was forged on the 1-ton hammer normally employed by the steelmaker in the manufacture of this particular steel, the other half was forged on the biggest hammer available at the works (2½ tons). Two more ingots were forged at another works on a large hammer and a heavy press. The effect of upset forging was tried on a piece of billet (*AFQ*) which had previously been forged to 2½ in. square; it was upset to a square plate 2½ in. thick and this was then forged down from one side to a bar 2½ in. square with its longitudinal axis at right-angles to that of the original billet. Some distortion tests were also carried out on specimens cut from a commercial sample of Swedish bar believed to have been forged from a 24-in. square ingot on a 900-ton press.

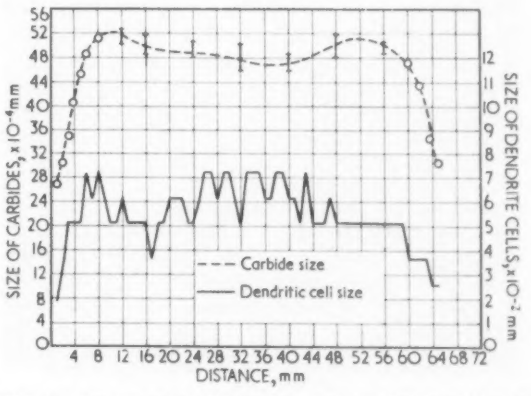


Fig. 4—Survey of carbide size and dendritic cell size across billet *AAK* forged on a 1-ton hammer

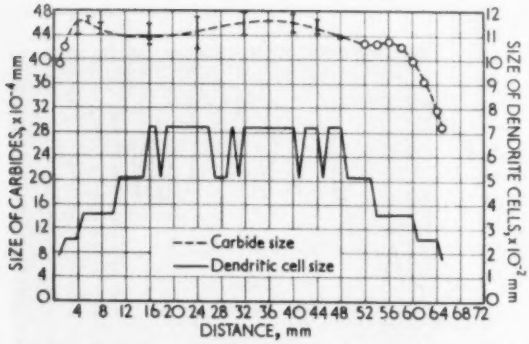


Fig. 5—Survey of carbide size and dendritic cell size across billet *ADB* (A) forged on a 1-ton hammer

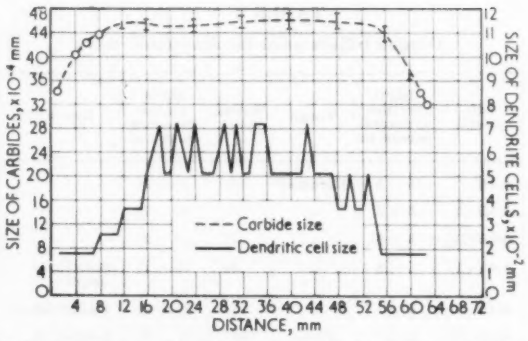


Fig. 7—Survey of carbide size and dendritic cell size across billet *ADX* (B) forged on a 3½-ton hammer

Cast distortion specimens

The Swedish steel bar (*ACN*) has received a forging treatment of exceptional severity and in any consideration of the effect of varying degrees of hot work, this bar represents one extreme. The other extreme will be a material with a cast structure unmodified by forging. Although it was possible to cut distortion specimens from a cast ingot the chances of reducing distortion were obviously greater in a cast structure free from gross segregation; this could be achieved in a small casting. In any case, cast dies would never be machined from large ingots but would be made in the form of small castings requiring relatively little machining. Facilities for precision casting were available in the laboratory and it was decided to cast individual distortion test-pieces. Several cast distortion specimens of the same composition as the 5-in. square steel ingot were produced by the Shaw moulding process. The surfaces on which distortion measurements were carried out were made oversize, and then ground; apart from this no machining was carried out before hardening.

Experimental procedure

The distortion test has already been described. Metallographic surveys were made across sections cut from an ingot, from the various forged bars, and from one of the cast specimens. A thin cross-section was cut from the ingots or bars and a ½-in. wide strip from the middle of this section was prepared for examination. The dendritic cell size was estimated by comparison with the standard ASTM grain size charts and the size of the chromium carbide particles was measured on a microscope using a calibrated measuring eyepiece. The results of the metallographic surveys are shown graphically in Figs. 2–9.

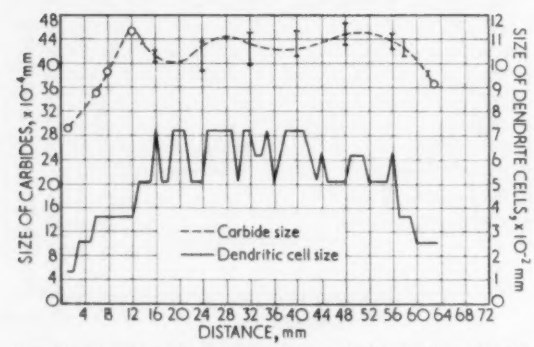


Fig. 6—Survey of carbide size and dendritic cell size across billet *ADB* (B) forged on a 2½-ton hammer

CONSIDERATION OF RESULTS

Effect of forging on structure and distortion

Metallographic surveys across half the cross-sections of two ingots are shown in Figs. 2 and 3. The size of the carbide particles and of the cells of the dendritic structure is plotted against the distance from the surface. The curves for carbide particle sizes of the two ingots are almost identical; there is a steep rise in particle size near the surface, extending about 12 mm inwards, and this is followed by a very shallow and gradual decrease in particle size towards the centre. The dendritic cell size is also smaller at the surface and increases gradually inwards, levelling off about 24 mm from the surface; this probably corresponds to the columnar crystals growing inwards from the mould wall.

Corresponding surveys across the entire cross-sections of the forged billets are shown in Figs. 4–9 and the results of the distortion test are given in Table II. Billet *AAK*, representative of normal production, is shown in Fig. 4. The carbide particle size near the centre of the billet is substantially

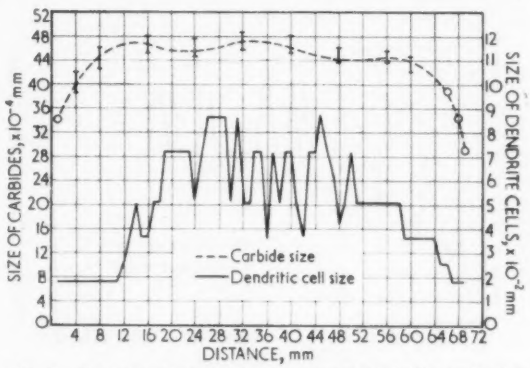


Fig. 8—Survey of carbide size and dendritic cell size across billet *ADW* (B) forged on a 600-ton press

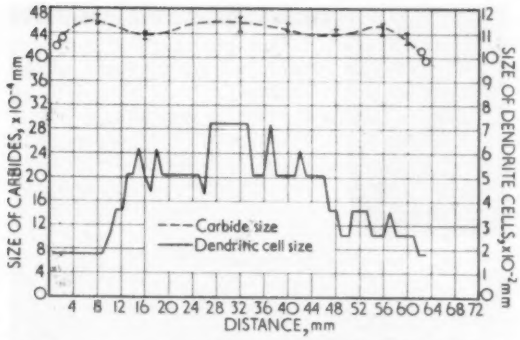


Fig. 9—Survey of carbide size and dendritic cell size across billet *AFQ* produced by upset forging

unaffected by the forging; the decrease in size towards the surface is much steeper than in the ingot and the peak is still about 12 mm from the surface. Since the section has been halved by forging, the original maximum in the ingot should be about 6 mm from the surface of the forged billet; it follows that the coarse carbides corresponding to the original maximum have been broken up by forging, like the carbide particles closer to the surface, which are smaller in the billet than in the ingot. It appears therefore that hot working has broken up the carbide particles to a depth of 12 mm in the billet, and has not affected those further in. Some of the billets (*ADB* (A), Fig. 5; *ADB* (B), Fig. 6; *ADW* (B), Fig. 8; and *AFQ*, Fig. 9) also have a shallow maximum in the carbide particle size near the core, but not always exactly central, corresponding to the macrosegregate.

The dendritic cell size at the surface of the billets is roughly similar to that in the ingots, but in the centre the network is much finer, pointing to effective hot working at the centre. In some billets there is a narrow band of very small cells at the surface, followed by an increase in cell size which is much steeper than in the ingots; in other cases this steep rise starts more or less at the surface. The levelling off towards the centre of the billet occurs about 12 to 16 mm from the surface, which corresponds to the 24-mm band of smaller dendrite cells found in the ingot.

The distribution of carbide particle sizes and dendritic cell sizes across the billet section is not always

TABLE II

Distortion of specimens cut from billets forged by different methods. Heat treatment: salt bath, ½–1 h 960° C, OQ + 1 h 200° C

Billet	Forging method	Specimen			
		A	B	C	D
AAK	Commercial stock Forged on 1-ton hammer	−13·9	+ 1·8	+12·5	...
ADB (A)	Forged on 1-ton hammer	− 7·0	+16·4	+ 7·1	+2·8
ADB (B)	Forged on 2½-ton hammer	− 3·9	−11·6	+ 4·5	...
ADX (A)	Forged on 3½-ton hammer	−26·6	+ 2·5	+11·6	−4·4
ADX (B) cropped end		−14·0	+ 3·7	+12·3	+1·4
ADW (A)	Forged on 600-ton press	−20·7	+13·0	+13·7	−2·4
ADW (B) cropped end		−23·2	+ 8·1	+ 8·7	−7·7
AFQ	Forged by upsetting	− 5·6 − 8·7	+ 6·5 + 8·8	+11·9 +15·6	−6·6 −7·5
ACN	Swedish steel forged from 24 in. sq. ingot to 2 in. × 1 in. billet on larger press			+ 7·5	+2·4

symmetrical and this may account for the asymmetry sometimes found in the distortion results. The disposition of the distortion specimens is shown in Figs. 4–9 and it can be seen that specimen *B* is taken from the central zone where the structure is generally uniform, so that its distortion depends on geometrical factors only, while specimens *A* and *C* have a sharp change in cross-section at a position corresponding to the peak in the particle size distribution and the midpoint of the steep rise in dendritic cell size. This confirms that the change in section is as close as possible to a boundary between two layers which differ in

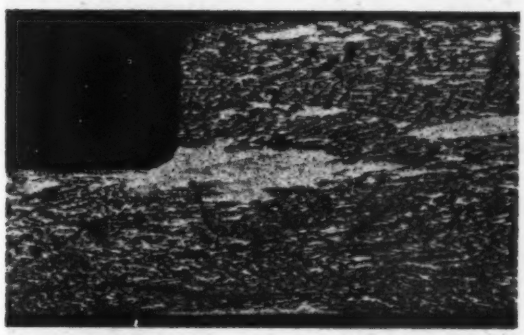


Fig. 10—Macrostructure of distortion specimen *ADB* (B) *B* showing patches of coarse segregate × 4

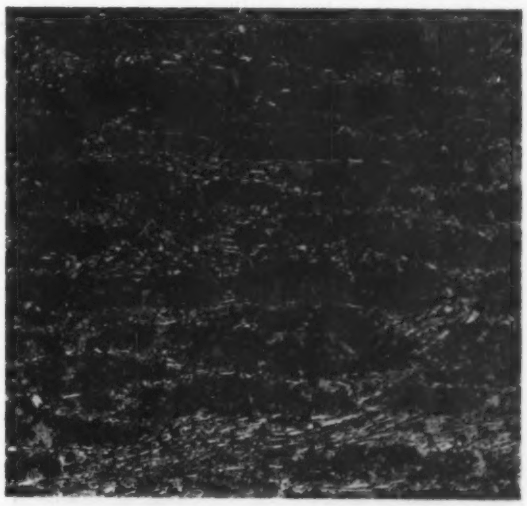


Fig. 11—Chromium carbides in dendritic zone of Fig. 10 × 100

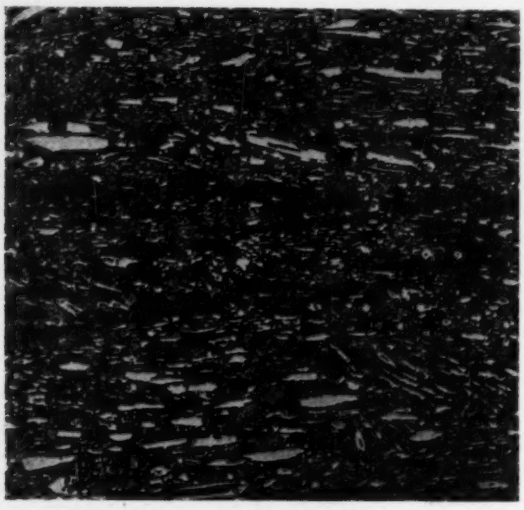


Fig. 12—Chromium carbides in segregated zone of Fig. 10 × 100

carbide distribution. As described above, the specimens are cut from the billets in such a way that differences in expansion behaviour of these two layers will cause them to bend in opposite directions. Table II shows that in billets *AAK* and *ADX*, which have a fairly symmetrical distribution of carbides and dendritic cell sizes (Figs. 4 and 7), the distortion of specimen *B* is slight, while specimens *A* and *C* were distorted about equally but in opposite senses.

Billet *ADB* (A) was forged on the 1-ton hammer used for the routine production of forged bar and should therefore correspond to the billets described above; any differences between them are due to chance and serve as a guide to the random error in this type of experiment. The distribution of dendritic cell sizes (Fig. 5) is very similar to billet *AAK*; the general level of carbide particle size is substantially lower and there is a segregate peak which is rather off-centre. Specimens *A* and *C* distorted rather less

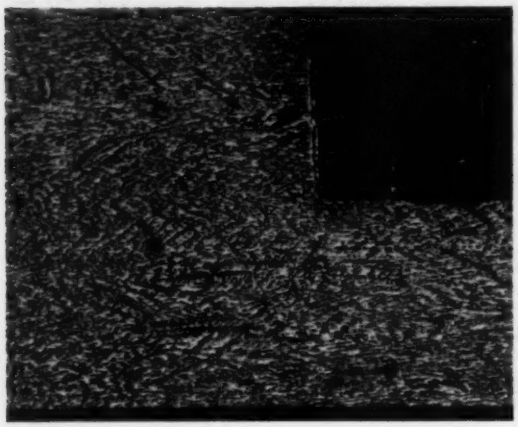


Fig. 13—Macrostructure of distortion specimen *ADX* (A) *B* showing random alignment of dendrites × 4

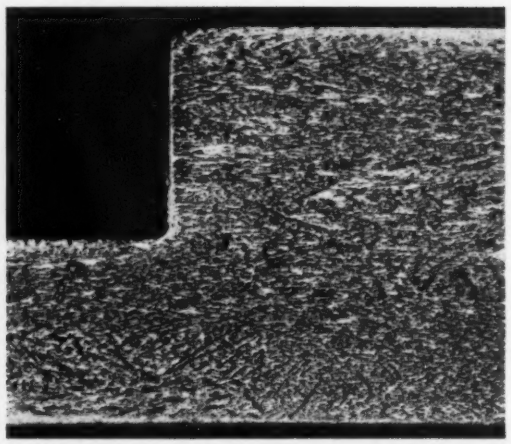


Fig. 14—Macrostructure of distortion specimen *ADW* (A) *B* showing break-up and longitudinal alignment of dendrites × 4

than those of billet *AAK*, but the distortion was again equal in magnitude and opposite in direction in the two specimens. Specimen *B* on the other hand showed very severe distortion; this may be associated with the off-centre peak in carbide particle size, i.e. with substantial differences in carbide structure between the two parts of the specimen. The billet forged on a 2½-ton hammer *ADB* (B) has a very similar carbide distribution (Fig. 6) and the distortion results show the same general characteristics, although the actual values for specimens *A* and *C* are exceptionally low. The macrostructure of the severely distorted (− 11·6) middle specimen from this billet, illustrated in Fig. 10, shows large areas of a coarse segregate especially rich in carbides. An exceptionally large patch is located at the actual change in section where it might be expected to have a particularly strong influence on distortion. The carbides in the dendritic and segregated zones are compared in Figs. 11 and 12;

Fig. 15—Chromium carbides in cast distortion specimen *AGJ* (3) × 100

they are much coarser in the segregate. It seems reasonable to attribute the severe distortion of some middle specimens to the presence of coarse segregate at vulnerable sites.

Forging on a 3½-ton hammer (billets *ADX*) has produced a rather more gradual change in carbide particle size near the surface (Fig. 7) and there was no maximum in the core; the distortion of specimen *B* is correspondingly low. The macrostructure of one of the middle specimens is shown in Fig. 13. The dendrites are aligned in all directions with only slight preference for longitudinal alignment.

Press-forging, billets *ADW* (A and B), gives a similarly smooth curve for carbide particle size (Fig. 8), this time with a slight maximum, centrally disposed. The dendritic cell size is appreciably smaller than in the corresponding ingot (cf. Figs. 3 and 8) and there appears to be a minimum near the core. This suggests that the centre of the billet has been worked rather more heavily in the press than on the hammers; whether this is due to the squeezing action of the press as such or to the effect of tool width must remain an open question. This is the only billet in which specimen *B* shows substantial distortion in the absence of an off-centre peak on the carbide particle-size curve. It is of course still possible that there was a gradient in carbide distribution across the actual specimen but the alternative explanation, that heavier working of the centre of the billet was responsible for the distortion of specimen *B*, cannot be excluded entirely. The macrostructure is illustrated in Fig. 14. Comparison with Fig. 13 indicates that the dendrites have been broken up and aligned in a longitudinal direction by press-work to a much greater extent than by hammer forging. The curve for the dendritic cell size in Fig. 8 is not symmetrical; there is a fairly gradual increase from the surface to the centre on one side, a sharp step on the other. This may explain the fact that the distortion of specimen *A* was so much greater than that of specimen *C*. The distortion specimens from billet *ADX* (A) behaved in a similar manner, but the cross-section used for the metallographic survey was taken from billet *ADX* (B), where specimens *A* and *C* showed the usual distortion characteristics.

It is not surprising that the upset forged billet *AFQ* had a very uniform carbide distribution. Figure 9 shows that the increase in dendritic cell size from the outside to the centre is sharper on one side of the billet than the other, and, as with billet *ADW* (B), there is a distinct difference in the degree of bending between specimens *A* and *C*.

TABLE III
Metallographic measurements on cast distortion, specimen *AGD* 1

Size of carbides, × 10^{-4} mm	Dendritic cell size, × 10^{-4} mm
46·8	5·07
50·4	5·07
48·5	5·07
50·3	7·18
45·6	7·18
47·5	5·08
41·2	5·08
46·6	5·08
48·5	5·08
45·6	5·08

The bar of Swedish steel (*ACN*) was only 2 in. × 1 in. so that only two distortion test-pieces could be cut from it. The structure was extremely uniform, showing evenly spaced planes of carbide stringers of substantially equal size. Specimen *C* in Table II was cut so that the carbide plates were parallel to the plane along which part of the material was removed to produce the thin section; it distorted to a moderate degree while the test-piece with the carbide at right-angles to this plane (specimen *D*) showed only the amount of distortion normally expected as a result of geometrical factors.

It appears from these results that neither an increase in the rating of the forging hammer, the use of a large press, nor even upset forging, has a very great effect on distortion. The least distortion was found in specimens from the centre of the billets, where the structure had been disturbed least, and where the dendrites still showed signs of the original cast structure. The relatively favourable distortion behaviour in this zone was only disturbed by segregation and

TABLE IV
Hardening of cast distortion specimens

Cast No.	Furnace	Successive heat treatments	Specimen					
			1	2	3	4	5	6
AGD	Salt bath	½ h 960° C OQ + 1 h 200° C	+ 3·6	+ 2·7				
	,, ,,	½ h 960° C OQ + 1 h 200° C	+ 1·7	− 1·7				
	,, ,,	½ h 960° C OQ + 1 h 200° C	...	+27·2				
AGJ	Salt bath	½ h 960° C OQ + 1 h 200° C	− 1·9	− 2·0	− 0·3			
	,, ,,	½ h 960° C OQ + 1 h 200° C	− 4·1	− 9·5	...			
	,, ,,	½ h 960° C OQ + 1 h 200° C	− 1·6	...	+ 1·5			
AHT	Salt bath	½ h 960° C OQ + 1 h 200° C	−12·5	− 8·9	− 4·8	− 6·9	− 8·0	− 8·0
	,, ,,	½ h 960° C OQ + 1 h 200° C	− 0·2	− 0·4	+ 2·5	− 9·6	− 5·5	+ 1·3

asymmetry effects originating in the cast ingot. Moreover, there is some evidence that even uniformly distributed carbide stringers lead to moderate distortion and there is a hint that an increase in the degree of hot working at the centre of the billet increases the sensitivity to distortion in subsequent heat-treatment. It can be inferred that one of the features of the structure responsible for distortion is the directionality of the carbide distribution and that the lowest distortion figures might be expected in small castings.

Distortion of cast specimens

Metallographic examination of the cross-section of a cast distortion test-piece (Table III) revealed a completely random distribution of carbide particle and dendritic cell sizes. The size of the carbides varies from $41{\cdot}2 \times 10^{-4}$ to $50{\cdot}4 \times 10^{-4}$ mm and is within the usual size range found in cast ingots and forged billets; it is somewhat surprising that the size of the casting has so little influence on the dimensions of the carbides. The size of the dendrite cells ranges from $5{\cdot}1 \times 10^{-2}$ to $7{\cdot}2 \times 10^{-2}$ mm, which corresponds to the cell size in the middle of the forged billets or to that at the transition from columnar to equiaxed grains in the ingots. Nevertheless the dendrites are too fine for reproduction in a macrostructure. The carbide distribution of a similar specimen is illustrated in Fig. 15. Comparison with Fig. 11 confirms that the particle size is roughly similar and the mesh size of the network of the dendritic cells is only a little finer; the main differences are that the cells are not elongated to anything like the same degree as in the forged billets and there is no longitudinal alignment.

Generally, the distortion figures obtained for cast distortion specimens after heat-treatment (Table IV) are within the range of $3{\cdot}6$ to $-12{\cdot}5$. In one case a figure of $+27{\cdot}2$ occurred but this was after a third hardening treatment, when other factors, such as decarburization during annealing, might supervene. These distortion results indicate that cast material may be less susceptible to distortion after heat-treatment than the forged billets.

This reduction in sensitivity to distortion on heat-treatment is not accompanied by a change in carbide particle size, but is associated with random arrangement of the dendrites. It confirms that a major cause of the difference in dilatation behaviour between adjacent layers, which is mainly responsible for distortion in the test employed in this work, is a variation in the degree of directionality of the carbides due to hot work. Specimens at the centre of forged billets consist of material taken from a feebly worked equiaxed zone and show relatively little distortion except where the coarse segregate occurs or where some material from the other zones is included in the specimen to form a second layer. Press-forging, which may work the central zone and impose some directionality on the carbides, has increased the sensitivity to distortion of specimens from the centre of the billet. This would imply that uniform directionality of the carbides itself, and not only variations in the degree of directionality, may cause some measure of distortion. The profound effect of the coarse carbide particles in the segregated zones underlines the importance of variations in particle size as another contributory factor to distortion.

ACKNOWLEDGMENTS

The authors are indebted to Messrs Jonas and Colver (Novo) Ltd and Messrs Wm Jessop and Sons Ltd for their co-operation with the forging programme, to a number of their colleagues at the GKN Group Research Laboratory for specialist services, to Mr F. D. Bridge, Manager of the Metals Division, for fruitful discussions and advice, and to Dr T. Emmerson, Director of Research, for permission to publish this paper.

Forthcoming Conferences and Exhibitions

Ergonomics—its place in industry

The Ergonomics Research Society is holding a conference on this theme at Balliol College, Oxford, from 6th to 9th April, under the chairmanship of the Master of Balliol; Mr Ernest Marples, M.P., the Postmaster General, will be the guest of honour at the opening reception.

The overall themes for the three operative days of the conference are "Ergonomics research since 1948" (7th April), "Laboratory and industrial studies and application" (8th April), and "Future trends and needs in ergonomics research" (9th April).

Full particulars of the programme, accommodation, etc. may be obtained from the conference secretary, Dr S. Griew, Department of Psychology, 22 Berkeley Square, Bristol 8.

Conference on crane safety

The Accident Prevention Committee of the British Iron and Steel Federation is holding a one-day conference on crane safety on 28th April, designed to give those interested in the subject an opportunity of discussing the report on "Crane Safety in the Iron and Steel Industry" published last September. The conference will be held at the Connaught Rooms, Great Queen Street, London W.C.2.

Société Française de Metallurgie

This year's Journées Métallurgiques d'Automne are to be held at the Maison de la Chimie, Paris, from 19th to 24th October. The theme of the meeting will be gases in metals.

Corrosion Exhibition

Sir Owen Wansbrough-Jones, K.B.E., C.B., Chief Scientist of the Ministry of Supply, is to open the 1959 Corrosion Exhibition on 27th April. Over 70 firms will be exhibiting at the Royal Horticultural Society's New Hall, Westminster, during the four days (27th–30th April) that the Exhibition is open.

Further information may be obtained from the organizers, "Corrosion Technology," Leonard Hill House, Eden Street, London N.W.1.

Skiing and metallurgy

St Christoph am Arlberg in the Austrian Tyrol will again be the setting for this year's 5th "Metallurgy–Skiing" meeting, organized by the Montanistiche Hochschule, Leoben, from 6th to 12th April. The subjects for discussion are dislocations, low- and high-temperature metallography, and stereo-electron microscopy.

Electrical Power Convention

"Electricity and its contribution to the standard of living" is to be the theme of the 11th British Electrical Power Convention, which is being held at Torquay from 1st to 5th June. As in former years, there will be an electrical exhibition associated with the convention. Particulars may be obtained from the British Electrical Development Association, 2 Savoy Hill, London W.C.2.

Engineering, Marine, Welding and Nuclear Energy Exhibition

Olympia will once again be the setting for this year's Engineering, Marine, Welding and Nuclear Energy Exhibition. It will be open from 16th to 30th April.

International Plastics Exhibition

More space is to be devoted to the machinery section in this year's International Plastics Exhibition, which is being held at Olympia, London, from 17th to 27th June. Materials, machinery, and finished products from 15 countries will be on show.

The effect of austenitizing treatment on formation of lower bainite in a plain carbon steel

By L. W. Graham, Ph.D., and H. J. Axon, D.Phil.

SYNOPSIS

The effects of solution-treatment temperature and time on the kinetics of the formation of lower bainite have been studied metallographically and dilatometrically for a 0·97% plain carbon steel. For macroscopically homogeneous specimens of austenite the early stages of transformation are accelerated when the austenite grain size is increased, although the time for complete transformation is insensitive to grain size. For homogeneous austenite of constant grain size the transformation characteristics are found to vary with austenitizing temperature in a thermally reversible manner: increasing the austenitizing temperature slows down the transformation and increases the volume change which accompanies it. The temperature- and time-dependent reversibility of these effects suggests that they arise from changes in the equilibrated solid solution and might be explained by the tendency for carbon atoms to cluster in the macroscopically homogeneous austenite. 1564

SINCE THE PIONEER WORK of Davenport and Bain[1] a great deal of attention has been given to the isothermal transformation of a wide range of plain carbon and alloy steels, but relatively little attention has been paid to the way in which the transformation characteristics of a particular steel may vary with variations in austenitizing treatment. At least two factors are important in such a study, namely the completeness with which the carbides are taken into solution in the austenite and the grain size of the austenite. Incomplete carbide solution may influence the transformation by controlling the true carbon content and macroscopic heterogeneity of the austenite or by providing nucleation sites for the precipitation of carbides during transformation at the higher temperatures. The influence of austenitic grain size on the pearlite transformation is relatively well established,[2] but it is also known that variations in the grain size of the solid solution affect the characteristics of martensitic transformation.[3, 6] A third phenomenon, that of clustering of solute atoms in the macroscopically homogeneous solid solution, must not be ignored when the reaction kinetics of isothermal transformations are examined.

Previous workers, in examining the effect of austenitizing treatment on the subsequent isothermal transformation to bainite, have obtained evidence which is conflicting. Allen, Pfeil, and Griffiths[7] have investigated the effect which increasing the austenitizing temperature has on the isothermal transformation of a 1%Cr steel. This treatment was found to have no detectable effect on the subsequent isothermal transformation to bainite, and since micro-examination indicated that raising the austenitizing temperature caused an increase in the grain size, it was concluded that an increase in the size of the austenite grains had no effect on the formation of bainite. Hultgren,[8] however, experimenting with a series of manganese steels, discovered that raising the austenitizing temperature caused a considerable retardation of both the incubation period and the transformation velocity on transforming to bainite. On the other hand, raising the austenitizing temperature has been found to accelerate both the inception and the transformation velocity of the austenite–bainite reaction in Ni–Cr–Mo steels.[9, 10]

An interesting feature of Cottrell and Ko's[10] work is that it was found possible partly to remove the accelerating effect of the high-temperature treatment by cooling the samples to a lower temperature in the austenite range before quenching. These findings were not confirmed in the same workers' investigations using Mn–Mo, Cr–Mo, 3%Ni, and *low*-carbon 1%Cr steels. In these materials the high-temperature heating had no effect on the bainitic transformation. A pronounced retardation of the onset of bainite formation and rate of transformation was observed as a result of raising the austenitizing temperature of a *high*-carbon 1%Cr steel.

The purpose of the present paper is to report the influence of austenitizing temperature on the lower

Manuscript received on 31st March, 1958.
The authors are at the Department of Metallurgy of the University of Manchester.

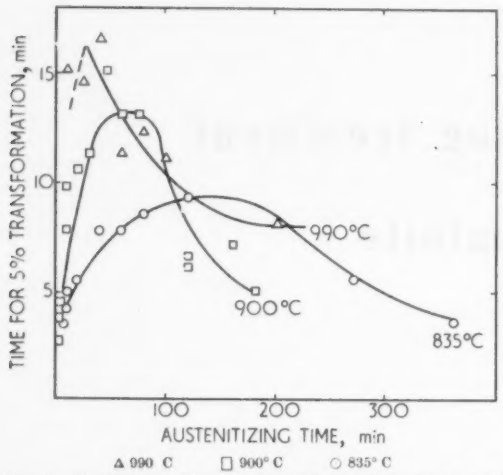


Fig. 1—Variation of 5% transformation time with austenitizing time at various temperatures

bainitic transformation of a plain carbon steel for conditions such that all the carbon is in solid solution in macroscopically homogeneous austenite of standardized grain size.

EXPERIMENTAL METHODS

The chemical analysis of the material was: 0·97%C; 0·14%Ni; 0·14%Cr; 0·13%Cu; 0·13%Si; and 0·16%Mn, and it was thus slightly hypereutectoid with an experimentally determined upper critical temperature of about 795° C (Ac_m.). It was received in the form of 0·75-in. dia. round bar which was swaged and drawn to 0·25 in. diameter. The 0·25-in. dia. rod was in the divorced pearlitic condition with rather massive carbide particles.

Nail-shaped dilatometer specimens were machined from the rod, with dimensions of 0·125 in. dia. by about 1·2 in. long. They were austenitized and

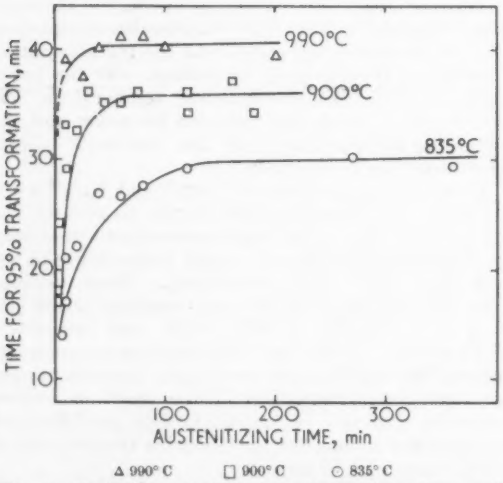


Fig. 2—Variation of 95% transformation time with austenitizing time at various temperatures

TABLE I

Austenitizing treatment and transformation characteristics at 266°C for 0·97% C steel

Austenitizing treatment		Transformation time, min.		Expansion, in./in. × 10^4
Temperature, °C	Time, min	5%	95%	
990	10	15·0	39·0	47·7
950	60	13·75	38·5	48·6
900	75	13·0	36·0	46·5
885	90	8·25	34·0	44·4
875	125	5·5	32·0	38·5
860	180	4·75	28·0	36·2
835	See text and Table II	4·0	29·0	26·1

All carbides in solution and grain size constant at ASTM 6

quenched in a silica saddle and push-rod assembly which was attached to a dial gauge graduated in 0·0001 in. An atmosphere of purified nitrogen was maintained in the austenitizing furnace to minimize decarburization, and in addition many specimens were nickel plated. A graphite sheath was employed to surround the specimen during the austenitizing treatment and during the period of transfer from the austenitizing furnace to the isothermal transformation bath, but it was not allowed to enter the transformation bath. The purpose of this sheath was to minimize loss of heat from the specimen during the process of transfer, but had the additional advantage of also preventing decarburization in the austenitizing furnace. The progress of isothermal transformation was followed by plotting dilation against time, particular attention being paid to the absolute amount of dilation.

A preliminary metallographic study of the M_s temperature was undertaken by the up-quenching method of Greninger and Troiano[11] using a specimen

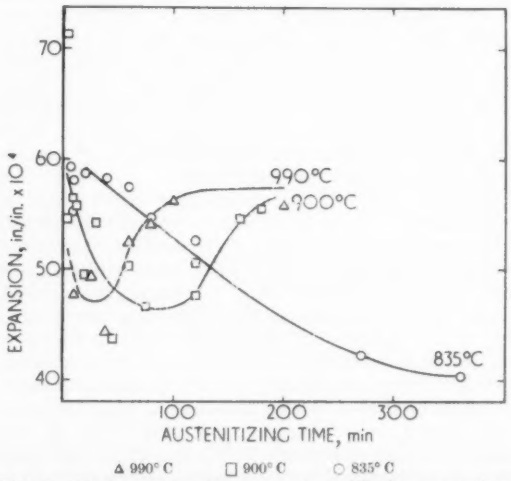
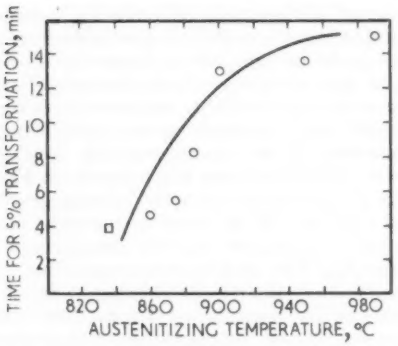


Fig. 3—Variation in the amount of dilation associated with complete transformation subsequent to various austenitizing periods at various temperatures



○ Single austenitizing treatment. □ Cyclic heat-treatment as indicated in Fig. 7

Fig. 4—Effect of austenitizing temperature on the time for 5% transformation. All specimens fully austenitized at constant grain size

size and heat-treatment technique as similar as possible to that used in the dilation experiments. This gave the M_s temperature as 196° C. Isothermal transformation at 266° C was found to take place within a reasonable time with the production of lower bainite and this temperature was used as the reaction temperature in all the work which follows.

EXPERIMENTAL RESULTS

Specimens were transformed at 266° C after being austenitized for times ranging from 4 to 360 min at temperatures of 835°, 900°, and 990° C. Complete dilation/time curves were obtained and the times required for 5% transformation and 95% transformation are plotted in Figs. 1 and 2 as a function of austenitizing time at the three temperatures. The influence of austenitizing time on the dilation, measured as in./in. $\times 10^4$ of the original specimen length, is indicated in Fig. 3. Microscopic examination of the isothermally reacted specimens showed that in no case was retained austenite present at the end of transformation and moreover there was no nodular troostite, indicating that a satisfactory quenching efficiency was obtained. Some of the specimens were found to contain undissolved carbides and in particular the last traces of carbide were not dissolved in an austenitizing time of less than 300 min at

TABLE II

Transformation characteristics at 266° C after austenitizing for 1 h at 945° C followed by treatment at 835° C

Holding time at 835° C, min	Transformation time, min		Expansion, in./in. × 10^4
	5%	95%	
1	12·5	40·5	55·3
5	9·0	39·0	55·3
20	9·0	34·5	49·1
40	8·0	38·0	45·3
80	10·0	31·0	36·2
120	4·5	30·0	32·4
160	8·0	29·5	32·2
205	4·0	29·0	26·1

All carbides in solution and grain size constant at ASTM 6

835° C, although carbide solution was complete within 45 min at 900° C and 10 min at 990° C. A micrographic determination of the austenitic grain size was also made on the fully reacted specimens of Fig. 1 and a marked increase of austenitic grain size was encountered during the later stages of the austenitizing treatment at each temperature. For austenitizing temperatures of 900° and 990° C the situation is fairly straightforward since for these temperatures the peaks in Fig. 1 are found at times which correspond roughly to a condition of complete carbide solution and the beginning of austenitic grain growth. Thus the curves for 990° C and 900° C indicate that the start of the bainitic reaction at 266° C is progressively retarded as carbide goes into solution in the austenite, but, with complete carbide solution the start of the reaction is progressively accelerated as the austenitic grain size increases. For an austenitizing temperature of 835° C austenitic grain growth is detectable before the last trace of carbide has gone into solution, but in this case also the onset of *grain growth* is found near the peak of the curve in Fig. 1.

Figure 2 indicates that the time for 95% transformation depends on the carbon content of the austenite, but that when all the carbides are dissolved an increase of austenitic grain size has no detectable effect on this reaction characteristic.

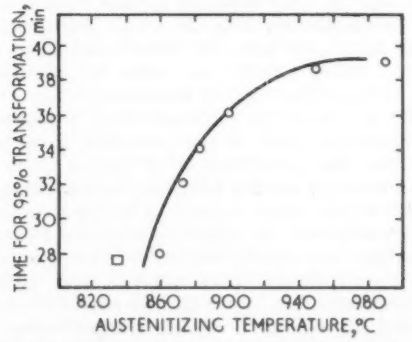


Fig. 5—Effect of austenitizing temperature on time for 95% transformation on the same specimens as in Fig. 4

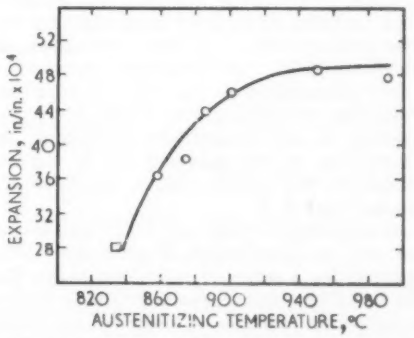


Fig. 6—Effect of austenitizing temperature on the dilation associated with complete transformation on the same specimens as in Fig. 4

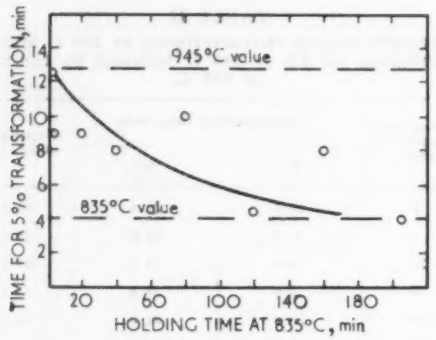


Fig. 7—Relation between 5% transformation time and period of holding at 835° C after soaking at 945° C for 60 min and cooling to 835° C. Standard grain size in all cases

Figure 3 indicates that the fractional dilation which accompanies the production of bainite at 266° C after austenitizing at 990° C and 900° C varies with the carbon content and grain size of the austenite in a manner similar to that already outlined for the 5% transformation times of Fig. 1. The dilation results for the specimens austenitized at 835° C are not strictly comparable with those for the other two austenitizing temperatures, since at 835° C carbide solution is very slow and grain growth takes place before all the carbides are dissolved.

The results collected in Figs. 1, 2, and 3 indicate that the bainite reaction is sensitive to the carbon content and grain size of the austenite and it is obvious that in any investigation of the effect of austenitizing temperature on the reaction these two factors must be held constant. This has been done in the work now to be reported, and is possible because the preliminary work gave an indication of the austenitizing time which was required to produce complete carbide solution and a particular grain size at 900° and 990° C. These results were used to estimate the austenitizing time required to produce complete carbide solution and an austenitic grain size at ASTM 6, for austenitizing temperatures of 990°, 950°, 900°, 885°, 875°, and 860° C.

It was not found possible to obtain carbide solution with the chosen grain size by a straightforward austenitizing treatment at temperatures below 860° C since the carbides dissolved too slowly to keep step with the grain growth. An alternative austenitizing treatment for 835° C was employed in which specimens were austenitized to the required grain size and with complete carbide solution at 945° C followed by slow cooling to and progressive holding at 835° C, the justification of this approach lies in the thermal reversibility of the equilibrium in the solid solution as indicated by Fig. 7.

The austenitizing conditions for complete carbide solution and the production of grain size ASTM 6, are collected for a series of temperatures in Table I together with the transformation characteristics of the specimens on reaction to lower bainite at 266° C.

Figures 4 and 5 indicate the way in which the time for 5% and 95% transformation at 266° C depends on austenitizing temperature and Fig. 6 indicates the variation of dilation with austenitizing temperature. Figures 4, 5, and 6 apply to specimens in which all the carbon is in solution in austenite of standard grain size; thus the observed retardation and increased dilation as the austenitizing temperature is increased must result from temperature-dependent changes in the structure of the macroscopically homogeneous austenite. The flattening of the curves in Figs. 4, 5, and 6 at temperatures above 950° C suggests that the detailed structure of the austenite is more markedly temperature dependent in the range 100–150° C above the Ac_m than at higher temperatures.

Table II shows the results of experiments in which specimens were austenitized to produce complete carbide solution and the standard grain size at 945° C and were then slowly cooled to 835° C and held there for increasing time intervals before being reacted at 266° C. Microscopic examination of the transformed specimens confirmed that the correct grain size had been obtained even after the most lengthy holding periods at 835° C. The influence of this treatment on the time for 5% transformation is indicated in Fig. 7.

DISCUSSION

The preliminary work reported in Figs. 1, 2, and 3 indicates that the characteristics of the lower bainite transformation depend on the austenitizing treatment. The specimens used in the present work contained fairly coarse carbide particles which went into solid solution very slowly at temperatures just above Ac_m but dissolved more rapidly as the austenitizing temperature was raised. Concentration gradients of dissolved carbon are certain to exist in the solid solution so long as dissolving carbides remain in the structure, but ignoring the effect of carbon concentration gradients the major effect of increased carbide dissolution is to increase the effective carbon content of the austenite and thus to increase the effective incubation period for transformation at a particular temperature. At the higher austenitizing temperatures carbide solution is followed by growth of the austenite grains. The rate of growth naturally varies with the heat-treatment temperature. For homogeneous austenite an increased grain size influences the transformation characteristics in the sense of decreasing the incubation period (Fig. 1) without markedly influencing the time required for the transformation to go to completion (Fig. 2) whilst the amount of dilation associated with the transformation increases (Fig. 3). These effects may arise in the following way: the transformation of austenite to bainite may formally be viewed as two elementary processes (the shear transformation of the austenite to a ferritic lattice and the precipitation of carbon from solid solution to form carbide particles) which overlap to a greater or less extent depending on the temperature of transformation. It appears reasonable to suppose that within any small volume of the system the carbide precipitation may precede the allotropic transformation of the lattice at high reaction temperatures and lag behind it at low temperatures. The allotropic transformation is accompanied by a volume expansion whilst the precipitation of carbon from the supersaturated solid solution is accompanied by a

contraction of volume, thus the total dilation on transformation is the result of the allotropic expansion offset by the carbide contraction. Each bainite plate nucleates and propagates in a single austenite grain, and the expansion associated with the formation of the bainite plate must strain the austenite matrix and set up in the matrix a back-pressure acting to prevent further transformation. Moreover the first bainite plate in any system must grow against the resistance imposed upon it by the matrix, and this matrix resistance is likely to be greater in a material of small grain size than in one of large grain size. Thus the ease with which the transformation commences depends upon the mechanical properties of the matrix and becomes greater as the grain size of the matrix increases. This is reflected in the decreased incubation period obtained as the grain sizes increases (Fig. 1). Not all the carbon is precipitated from solid solution in the production of lower bainite[12] and the amount of carbide precipiation influences the overall dilation. In lower bainite the precipitation of carbide may be visualized as relaxing the matrix back-pressure which is set up by the allotropic expansion of the bainite plate, and with a matrix of large grain size the matrix back-pressure set up by a given amount of bainitic transformation is less than with a matrix of small gain size. Thus in the large-grained matrix a less degree of carbide precipitation is required to counteract the smaller matrix stresses and hence the overall transformation dilation increases (Fig. 3). The time required for the completion of transformation (Fig. 2) is insensitive to the original austenitic grain size, presumably because the important consideration at any degree of transformation is the size of the regions of untransformed austenite and the partitioning effect of the growing bainite plates will eventually reduce these regions to a small size irrespective of the original austenitic grain size.

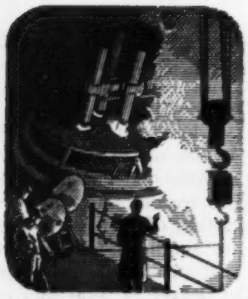
The results plotted in Figs. 4, 5, and 6 are independent of the variations due to composition and grain size discussed above, and indicate that for homogeneous austenite of controlled grain size the transformation characteristics vary with austenitizing temperature.

Figures 4 and 5 indicate that in material of specified carbon content and grain size the time required for the beginning and end of the bainitic reaction increases as the austenitizing temperature is raised and Fig. 6 indicates that this slowing-down of the reaction is accompanied by an increased dilation. The reason for this behaviour must be sought in the detailed structure of the solid solution. Thompson and Chaudhuri[13] have used the Eggertz colour carbon test to demonstrate a change in the physico-chemical properties of austenite quenched from different temperatures and have interpreted their results in terms of a proposed reversible equilibrium between atomic and molecular carbon in solid solution. An alternative way of viewing the effect is to consider the dissolved carbon as having a tendency to cluster in the solid solution, the clustering becoming less pronounced as the temperature is raised owing to the homogenizing effect of thermal vibrations. Austenite in which carbon clusters exist may be of particular significance in connection with the bainite transformation, since the presence of a region of solid solution highly enriched with respect to carbon not only provides the nucleus for carbide precipitation but, by provoking in the solid solution adjacent areas correspondingly denuded of carbon, provides also the carbon-poor regions of the lattice which are regarded as the nuclei for the lattice transformation. Thus the degree of carbon clustering in equilibrated austenite may be related to the population of both the ferritic and carbide nuclei which are required for the propagation of bainite. Higher austenitizing temperatures are associated with a smaller degree of solid-solution clustering and hence fewer nuclei and a longer incubation period for the bainite reaction, as shown in Fig. 4. The increased dilation which accompanies the bainite transformation after austenitization at the higher temperatures may arise either by virtue of the smaller number of more widely dispersed carbide nuclei being insufficient to act as precipitation sinks for the whole volume of the solid solution, thus decreasing the total amount of carbide which may precipitate in a given time, or by virtue of a change in the mechanical properties of the matrix due to the decreased clustering of dissolved carbon atoms in the austenite reducing the matrix back-pressure set up by a given amount of transformation.

That the effects represented in Figs. 4, 5, and 6 are associated with the properties of the equilibrated austenite solid solution as they vary with temperature is shown in Table II and Fig. 7, from which it may be seen that the reaction characteristics appropriate to 945° C progressively alter with time of holding at a lower temperature within the homogeneous austenite phase field. This type of experiment allows measurements of reaction characteristics to be made in the temperature range where, because of grain growth before the complete dissolution of carbide, it is not possible to obtain an equilibrated austenite of controlled grain size by a single austenitizing treatment.

REFERENCES

1. E. S. Davenport and E. C. Bain: *Trans AIME*, 1930, vol. 90, pp. 117–144.
2. R. F. Mehl and W. C. Hagel: *Progress in Metal Physics*, 1956, vol. 6, pp. 74–134.
3. E. A. Owen and D. Madoc Jones: *Proc. Phys. Soc.*, 1951, vol. 67B, pp. 456–466.
4. E. Scheil: *Zeitschrift für anorganische und allgemeine Chemie*, 1932, vol. 207, pp. 21–40.
5. W. J. Barnett and A. R. Troiano: *Metals Technology*, 1948, vol. 15. *AIME*, Tech. Publ. 2417.
6. W. J. Harris and M. Cohen: *Trans AIME*, 1949, vol. 180, 447–469.
7. N. P. Allen, L. B. Pfeil, and W. T. Griffiths: Second Report of the Alloy Steels Research Committee, *ISI Spec. Rep.* No. 24, pp. 369–390, 1939.
8. A. Hultgren: *Trans. ASM*, 1947, vol. 39, pp. 915–1005.
9. K. Winterton: *JISI*, 1945, vol. 151, No. 1, pp. 79P–91P.
10. S. A. Cottrell and T. Ko: *Ibid.*, 1953, vol. 173, pp. 225–228.
11. A. B. Greninger and A. R. Troiano: *Trans AIME*, 1940, vol. 140, pp. 307–321.
12. H. J. Axon, L. W. Graham, and P. Vasudevan: *JISI*, 1958, vol. 190, pp. 386–391.
13. F. C. Thompson and A. R. Chaudhuri: *JISI*, 1954, vol. 178, pp. 44–50.



IRON AND STEELWORKS ENGINEERING

The Iron and Steel Engineers Group

Equipment used for vacuum melting and casting in the iron and steel industry

By A. S. D. Barrett and M. E. Harper

SYNOPSIS

The opportunities offered by vacuum metallurgy to meet the stringent needs of designers in the aircraft and allied industries has greatly stimulated the development of equipment for vacuum melting and casting. The requirements of the metal producer range from versatile research and pilot plant equipments to production equipments of 5 cwt and above having all the facilities of a research unit. The advantages of vacuum treatment may also be largely realized over a wide range of metals and alloys, where economically the full treatment of high-vacuum melting is not required with certain types of vacuum-degassing units. Thus the use of a vacuum induction holding furnace working in a duplex manner with conventional air furnaces has much to commend it in the recovery of scrap and the production of consistently high-quality material. The extension of the principle of liquid charging may embrace a higher degree of vacuum treatment followed by vacuum casting. The experience gained in the natural development of vacuum furnaces from the laboratory to the foundry floor will materially affect the future simplification of this type of equipment. Simplification would seem obviously to follow from the use of new bottom pouring methods in conjunction with continuous casting equipment. 1653

THE TONNAGE PRODUCTION of the special alloy industry compared with the tonnage production of the iron and steel industry as a whole is relatively small, but this, of course, is not a true comparison of the value of the special alloy industry. In the past 50 years there have been great developments in both ferrous and non-ferrous alloys, without which modern developments such as turbine engines, machine tools, etc. would not have been possible. The replacement of the old type of crucible furnace by the high-frequency induction furnace has contributed greatly, not only to the working conditions experienced by the melter but also significantly in efficiency of production and control of alloy compositions. Following designers' ever-increasing demands for new and improved alloys, the special alloy industry has had to turn to new and improved methods of production. The complex composition of many of the alloys in use and the even greater complexity of those being developed have directed research for new methods of production into the field of high-vacuum metallurgy.

The use of vacuum removes dissolved gases and volatile impurities from the melt, reduces metal oxides by the carbon–oxygen reaction occurring at low pressures, and eliminates the effects of atmospheric contamination. The result of these conditions is a metal of consistently high quality with an accurately controlled composition. This demand on the alloy industry has produced a corresponding demand on the high-vacuum engineering industry, and it is fortunate that the developments that have had to be made to ensure the progress of atomic-energy projects have enabled what was previously small-scale research-laboratory work to be translated into production equipment capable of standing the rigours of the foundry floor.

Manuscript received on 27th October, 1958.
The authors are with Efco-Edwards Vacuum Metallurgy Ltd.

RESEARCH AND PILOT-PLANT EQUIPMENT

New techniques, however, do not develop nor are they accepted overnight. Coupled with this is the increasing need of the research metallurgist to investigate and develop alloys that can derive the maximum benefit from vacuum treatment. For this purpose a versatile vacuum melting and casting furnace whose performance for research and development work can be translated to production-size equipment is of the utmost importance. It is highly desirable that such a furnace is capable of operation by normal foundry personnel for small-scale production, thus making robust construction essential.

The furnace illustrated in Fig. 1 is a standard 56-lb vacuum melting and casting furnace whose capacity can be varied from 28 to 100 lb by the use of interchangeable h.f. melting assemblies. The use of h.f. induction heating is an obvious choice for a vacuum furnace using a refractory crucible, as the importance of stirring in vacuum melting is not limited to the mixing of alloys alone, but it also facilitates gas removal and the reduction of oxides, which is believed to be primarily a surface phenomenon. However, the incorporation of an induction-heated furnace into a vacuum chamber is not without its difficulties, owing to the limitations imposed by gas-discharge phenomena. Thus it is readily seen that an efficient furnace must be designed electrically having consideration for the vacuum and *vice versa*.

High-frequency power supply

The use of a bare conductor inside the vacuum furnace imposes a limitation of voltage to less than 200 V, to ensure prevention of a corona discharge over the complete range of operating conditions. However, the limitation in voltage leads to a corresponding increase in the current to be carried by the h.f. coil assembly and also to a decrease in the power factor. Greater efficiency and flexibility of the electrical equipment is obtained by the use of voltages in excess of 200 V, an optimum power supply for an efficient research furnace of this size being 50 kW, 400 V, 5 000 c/s.

Special insulating techniques were developed that enabled these voltages to be used without formation of corona discharge, and if the insulation is damaged in any way during operation the main h.f. power is immediately isolated by the use of an earth-leakage protection system. This system requires completely insulated h.f. leads and the earthing of the charge and all other parts of the plant, a feature which ensures maximum safety in operation to both the plant and the operator.

The h.f. power is conveyed from a remotely operated capacitor cubicle by water-cooled flexible cables to the h.f. coil assembly and fully insulated rotating coaxial seal. The coaxial seal, cantilevered from double thrust races external to the vacuum system, supports the melting-furnace framework, in which the h.f. coil is clamped so that no stress is taken by the coil or its associated leads. An earth pole is fitted in the base of the melting assembly for earthing the charge through the base of the crucible and is used in conjunction with the earth-leakage protection system.

Fig. 1—56-lb vacuum-induction melting and casting furnace (*by courtesy of G. L. Willan Ltd, Sheffield*)

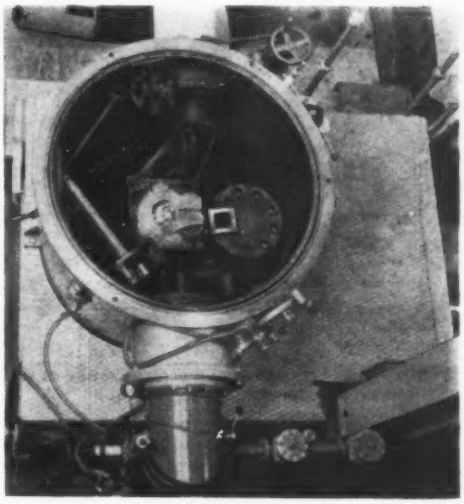


Fig. 2—Interior of 56-lb furnace (*by courtesy of Sheffield University*)

General construction

The vacuum chamber containing the furnace assembly is of substantial steel construction and is double-jacketed for water-cooling over its upper portion. The vacuum chamber is mounted vertically and is closed by a double-jacketed water-cooled lid formed from pressed dished ends to resist effectively the combined effects of water and atmospheric pressure. The vacuum seal between lid and chamber is effected by the use of an O ring contained in a trapezoidal groove dimensioned to give metal-to-metal contact between the mating flanges. The sealing face in the lid is recessed to leave a protruding rim, which allows the lid to be stood down on a flat surface without fear of damage to the sealing face. Removal of the lid is carried out by either a hoist or an integral hydraulic lift and slew mechanism. The lid contains a 6-in. dia. observation window fitted with a radiation screen and flexible wiper assembly which ensures visibility throughout the process, irrespective of the effects of condensable metal vapours. Provision is made at a position directly above the melting crucible for the future addition of a vacuum lock to a port which normally contains a tubular ramrod assembly operating through a universal vacuum joint. Besides being invaluable in breaking down bridged melts, this ramrod enables gases such as hydrogen to be admitted directly to the melt surface.

Figure 2 shows a general view of the interior of the furnace and illustrates the charging mechanisms and immersion pyrometers. After the initial charge has been melted, up to one-third of the total charge may be added from a bottom-opening bucket operated from a swinging arm. A small alloy charger allows a random choice of alloying constituents to be made

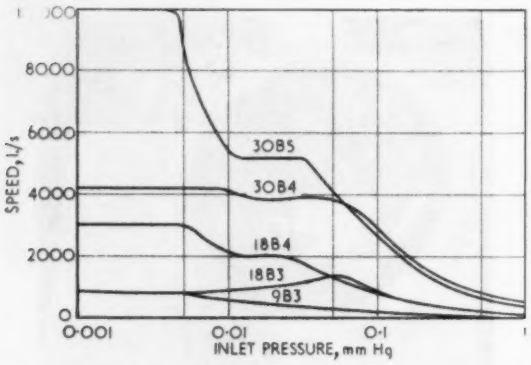


Fig. 3—Performance curves of a typical range of vapour booster diffusion pumps

from any one of six vertical cylinders each fitted with a bottom-opening shutter, selection being made on a dial external to the furnace and the addition transferred to the melting crucible by means of a small bottom-opening bucket.

Temperature measurement is by two immersion pyrometers, one being a safeguard against failure of the other during the melting operation. A temperature range of 0–1800° C is covered by a thermocouple of composition 5%Pt–Rh/20%Pt–Rh housed in a tubular stainless-steel U-shaped arm, which has surplus wire stored in a junction box pivoted to connect a tilting arm operated by an external lever. The pyrometer sheath is sealed into a stainless-steel holder and is attached to the other end of the pyrometer tube. Excellent life and results have been obtained from Metamic sheaths manufactured by the Morgan Crucible Co. Ltd, and one in particular, a molybdenum–alumina mixture, provides for as many as 30 dips with insertion times of up to 2 min each, thus ensuring that thermal equilibrium is obtained for each temperature measurement.

Other provisions in the furnace include a spring-loaded pressure-relief port with facilities for incorporating water leads for cooled moulds and electrical connections for conveying power to the furnace interior. In casting single ingots the mould is mounted on a platform of variable height to accommodate various mould lengths. Where multiple castings are desired from the one melt, moulds are mounted on a turntable, which replaces the single mould-support platform.

Vacuum-pumping equipment

A 16-in. dia. evacuation port in the side of the chamber connects to a vacuum-pumping combination which may be varied for specific applications. The standard combination used employs a special type of vapour-booster diffusion pump developed for metallurgical and allied processes, in which large gas evolution occurs in the pressure range 0·5 to 10^{-3} mm Hg, where the conventional vapour diffusion pump and rotary mechanical pump have low speeds; the performance curve for one of these pumps type number 18*B*3) is shown in Fig. 3. The vapour-booster diffusion pump also provides a vapour diffusion pump characteristic down to a vapour ultimate of 10^{-4} mm Hg corresponding to a partial air ultimate of less than 10^{-6} mm Hg. The speed of the pump when pumping light gases is considerably increased above its pumping speed for air. For example, hydrogen is pumped over twice as fast as air, an obvious advantage in melting processes. An outstanding feature of the pump is its ability to work against a backing pressure as high as 3 mm Hg, thus enabling it to be used in the pumping cycle at a point where the volumetric efficiency of the rotary pump is still high, and this leads to a considerable reduction in the time to carry out the pumping cycle. By virtue of its high backing pressure, effective backing is obtained by a single-stage rotary mechanical pump to which full air-ballasting may be applied with no deterioration in the performance of the vapour-booster diffusion pump. The working fluid is relatively inexpensive and very robust. It has no flashpoint and is contained in a boiler large enough to permit long running of the pump, even in dusty conditions, before renewal of the fluid becomes necessary.

Pressure measurement

Pressure measurement is carried out by a combination of three gauges, a capsule dial-gauge covering pressure measurement from 1 mm Hg to atmospheric pressure, a Pirani thermal-conductivity gauge covering the pressure range from 5×10^{-3} to 10 mm Hg in two scales, and a Penning-type cold cathode ionization gauge for pressures below 5×10^{-3} mm Hg. The last-mentioned gauge has given consistent results even under severe contaminating conditions. The Pirani gauge, however, is quickly contaminated under normal operating conditions, but it is very useful as an indication of which gas is predominant in the furnace atmosphere. Recent developments have made this gauge much more reliable, the major cause of deterioration of the gauge being blackening of the filament during repeated furnace operations. The gauge heads are now produced with a blackened filament, and subsequent contamination no longer has a serious effect on the calibration of the gauge.

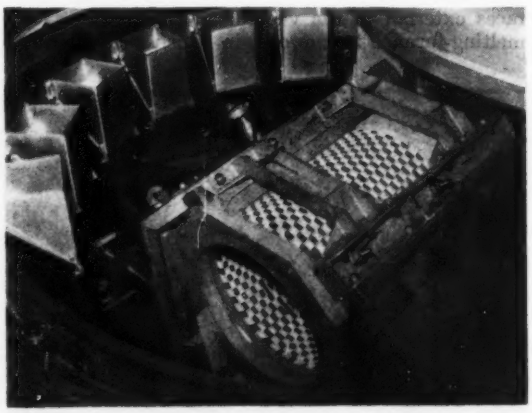


Fig. 4—5-cwt vacuum-induction melting and casting furnace (*by courtesy of Telegraph Construction and Maintenance Co. Ltd, Crawley*)

Fig. 5—15-cwt vacuum-induction holding furnace (*by courtesy of Sheepbridge Alloy Castings Ltd, Sutton-in-Ashfield*)

Melting cycle

A typical melting cycle of the furnace for, say 56 lb of nickel alloy, from the start of evacuation to the casting of the ingot, which includes melting time, alloying, and vacuum treatments, is 55 min, the pressure at casting being 0·5–1·0 μ. It is common practice to pump throughout the melting cycle, controlling the vigour of a carbon boil by an appropriate restriction of pump speed but in no instance allowing the boil to subside, as in this way it has been found that fast melting cycles can be achieved with a maximum amount of degassing and refining.

PRODUCTION EQUIPMENT

Conventional vacuum-induction furnaces

The success of the 56-lb furnace as a robust experimental unit contributed greatly to the design of a 5-cwt capacity vacuum-induction melting and casting furnace. Although there are many arguments in favour of using a horizontal furnace chamber as against a vertical one, one of the most important factors in vacuum melting is the condition of the crucible lining, as the good done by vacuum treatment can be undone if the lining has deteriorated. Regular inspection is required and, until there is a horizontal chamber sufficiently large to permit easy access, best access to the furnace is given by a vertical chamber. However, if it is necessary to cast multiples of small ingots from one melt, ease of mould handling becomes a predominant factor, which is best solved by a horizontal furnace chamber.

The 5-cwt furnace is shown in Fig. 4; it incorporates all the features of the research-size furnace. Special consideration has been given to the problem of changing makeup and alloy additions, since where complicated alloys are required to be made it is desirable that the capacity of the charging system should be at least half the total capacity of the melt. The charging system of this furnace uses a system of buckets which travel on the inner periphery of the vacuum chamber and are constructed with drop-away flaps that are released by the action of a transfer chute when charging the crucible; the operator is informed which bucket is in the charging position by an indicator on the selecting mechanism. Preselection may be made on this system, which is designed for random operation to give maximum flexibility during the melting operation. The casting of multiple moulds is catered for by the provision of a turntable situated beneath the h.f. melting assembly, and moulds positioned on it are rotated clear of the furnace assembly.

Although the furnace is designed with provision for future incorporation of vacuum locks to enable a semi-continuous operation to be carried out, careful consideration both from economic and maintenance viewpoints has shown that, with a furnace of this capacity, semi-continuous operation is better replaced by twin furnace units operating from one h.f. power supply. In this way the power is used continually and the whole of the melting time of one furnace is available for stripping and recharging the second furnace, which may then be evacuated and made ready to start melting immediately the pouring operation of the other furnace has ended. Melting staff is kept to a minimum in this way and no time is wasted. This arrangement also ensures that production still continues when the relining of one furnace is necessary. Such operation enables an inspection of the refractory lining to be made between melts, and regular running of the furnaces is ensured.

The vacuum pumping-equipment normally used on a furnace of this size is a type 30*B*4 vapour-booster diffusion pump working in conjunction with a 300-ft³/min air-ballasted rotary mechanical pump. The performance curve of the 30*B*4 vapour-booster diffusion pump is given in Fig. 3. The vacuum valves associated with this furnace are suitable for compressed-air operation and are remotely operated from a sequence-control unit which provides the operator with an indication of each stage of the pumping cycle.

Whilst undoubtedly there will continue to be a demand for furnaces of capacities of 1 ton or greater

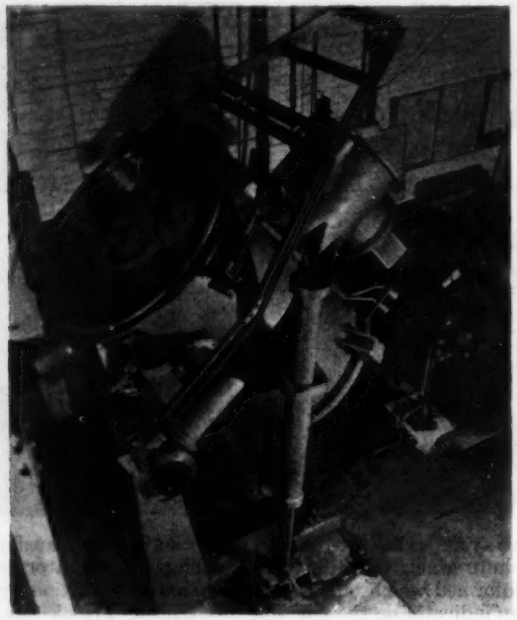


Fig. 6—Hydraulic tilting mechanism of 15-cwt vacuum-induction holding furnace

incorporating all the features of high-vacuum induction melting, the cost of operation of such a furnace should be carefully considered in relation to the material being produced. Such furnaces require careful selection of the initial melting charge and the form the makeup additions will take. There are also electrical problems when the h.f. power required approaches 750 kW.

Induction degassing process

Because relatively few alloys can stand the premium that would have to be charged for true high-vacuum induction melting and casting, careful consideration was given by Efco-Edwards to the design of a furnace that could produce materials with many of the advantages of treated vacuum induction-melted material. Bearing in mind the degree of improvement that can be obtained in relation to an economic carrying cost, the furnace designed and built to meet this need was a vacuum-induction holding furnace capable of operation from an existing h.f. installation and working in conjunction with normal air-melting furnaces, which supply a liquid charge that is transferred to the vacuum-induction holding furnace.

In considering the use of this principle, it is necessary to review two other vacuum processes, stream degassing and vacuum-arc melting. For example, the use of stream degassing in the special alloy industry offers only a limited improvement, mainly with respect to the reduction of hydrogen to a little better than 50%. Also, the temperature drop experienced when only a small tonnage is processed at one time necessitates either a high degree of superheat before treatment or reheating after treatment, a procedure that invariably cancels the effect of the treatment. The use of the vacuum-arc furnace requires the preparation of the alloy into the form of an electrode by conventional melting practice, and for certain alloys the vacuum arc process does not offer the same degree of improvement or the closeness of composition control as the vacuum induction furnace. Its ideal form of operation is the remelting of an alloy charge prepared by vacuum-induction melting, but this leads to an extremely high total melting cost.

The vacuum-induction holding furnace has many of the advantages of vacuum-induction melting but at a fraction of the operating cost of these furnaces. To differentiate this method of improving metal quality upon the already well established vacuum-melting process, the term ' I.D.' (induction degassing) process is proposed. An early application of this process arose from a company manufacturing centrifugal castings in a wide range of Ni–Cr and iron alloys with low hydrogen, lead, and non-metallic inclusion contents to ensure good mechanical properties and freedom from hydrogen porosity and inclusions. Existing air-melting techniques, aggravated by the need to reclaim as great a percentage of scrap as possible gave rise to castings with faults that were not fully revealed until costly machining operations had been carried out. With the accent on simplicity of design and operation, the furnace illustrated in Fig. 5 was constructed to produce centrifugal castings from metal treated by the I.D. process at a comparatively small additional cost. This was done by installing a vacuum furnace of 15 cwt capacity to operate in a duplex manner with conventional air-melting furnaces from an existing h.f. power supply.

Fig. 7—Air-tapping the 15-cwt vacuum-induction holding furnace *(by courtesy of Sheepbridge Alloy Castings Ltd)*

General construction

A vacuum chamber 4 ft dia. × 6 ft high, accommodating a conventional mechanically shielded steel-cased h.f. furnace assembly, is fitted with a removable water-cooled lid which incorporates an observation window internally fitted with a cleaning device. The h.f. coil leads are brought out of the rear of the vacuum chamber via a static seal and terminate in connections for the attachment of flexible water-cooled h.f. power cables. A horizontal 2-ft dia. port is incorporated for easy access to the internal connections of the seal and the blanking plate to this port is fitted with a spring-loaded pressure-relief disc to ensure safety of operation. The pouring spout of the crucible assembly is aligned with a tapping spout built into the chamber wall and sealed during the degassing operation by a cap cover. The vacuum chamber is carried on trunnions positioned approximately at the tapping-spout axis and supported by a rigid frame. Tilting is by means of two hydraulic cylinders mounted on the frame and acting on trunnion pins attached to the chamber body (*see* Fig. 6). The crucible has an internal diameter of 20 in. and is 32 in. deep; this provides for 15 cwt of metal attaining a height of about 22 in., leaving 10 in. to accommodate any increase in metal height during the degassing process. A cast refractory lid covers the crucible during degassing to eliminate loss of heat by radiation and to restrict metal splashes to the crucible. The refractory lid has a small hole which coincides with the observation port in the chamber lid, permitting visual inspection of the metal. A rotating vacuum seal is positioned at the tilting axis and connects the vacuum chamber via an 8-in. dia. exhaust pipe to a vacuum pumping unit consisting of an air-ballasted rotary mechanical pump backing a Roots-type vacuum pump with a high gas-handling characteristic in the millimetre pressure region.

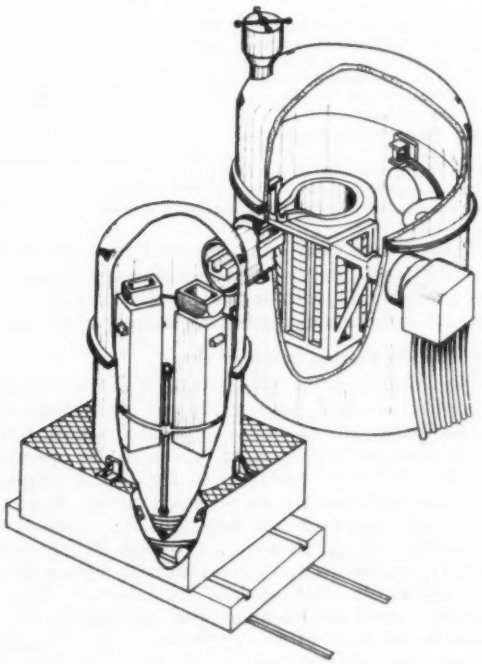


Fig. 8—Stationary-chamber vacuum-induction holding furnace and mould chamber

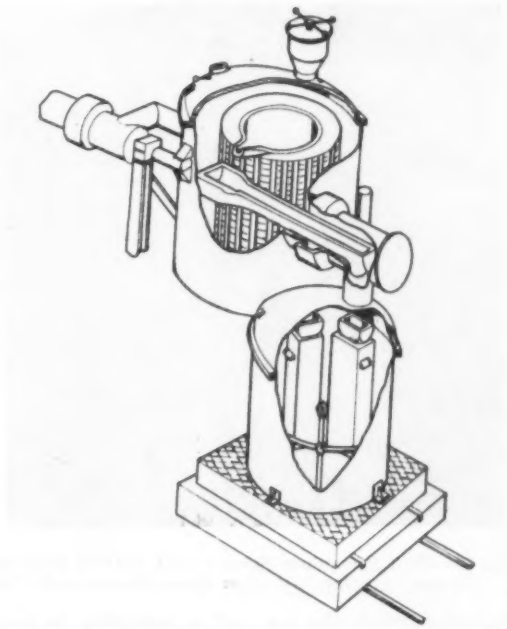


Fig. 9—Tilting-chamber vacuum-induction holding furnace and mould chamber

Economy of power requirement

In operation the furnace is charged with liquid metal air-melted in the normal way and transferred to the crucible by a teapot ladle. Full power is applied to the furnace coil to make up for the temperature drop that occurs during transfer and, when the temperature at which degassing is to be carried out is reached, the chamber lid is placed in position and evacuation begins. During degassing it is only necessary to supply h.f. power to compensate for heat losses and to provide adequate stirring of the melt to promote degassing and the carbon–oxygen reaction. After degassing, the vacuum is released, the metal is tapped in air (Fig. 7), and the normal casting procedure is carried out.

To meet the requirements of the process, a h.f. coil was designed to be connected to an existing 400-kW motor-generator set which, by the use of a change-over switch, could be fed either to an existing air melting furnace or the vacuum furnace. This arrangement is particularly attractive, as the advantages of vacuum degassing are obtained without incorporating the additional capital expenditure of a new motor generator. The coil design allows the full generator rating (400 kW) at a relatively high voltage (about 1 100 V) to be applied in air, thus enabling a rapid boost in temperature of the initial liquid charge to be obtained as well as providing for the operation of the furnace as an air-melting installation. During

Fig. 10—200-kg uranium furnace with bottom pouring *(by courtesy of the Australian Atomic Energy Authority)*

degassing, when the h.f. coil is subjected to low-pressure conditions, the power required to hold the temperature of the melt constant is of the order of 120 kW, and this is obtained with a coil voltage not exceeding 400 V, thus ensuring that with existing insulating techniques formation of corona discharge is obviated. As an extra safeguard, the furnace is fitted with an earth-leakage protection system and, as with all vacuum-induction furnaces, this system is invaluable in preventing dangerous conditions arising in the furnace.

Degassing cycle

The degree of refinement of the melt during the degassing process is governed by three main factors; (*a*) temperature, (*b*) pressure, and (*c*) time. In this plant a total process time of 15 min was found to be adequate for the production of clean, sound castings. During this 15-min cycle the furnace is evacuated by the rotary mechanical pump from atmospheric pressure down to 10 mm Hg, at which stage a pressure switch brings into action the Roots pump, which has a displacement of 1 000 ft³/min over the pressure range 10^{-2}–10 mm Hg. During the rest of the process time the furnace pressure is reduced to about 0·5 mm Hg. The behaviour of the melt during the process passes through three characteristic stages. First, when the pressure has been reduced to about $\frac{1}{2}$ atm, turbulence of the melt occurs and dense fumes are given off. As the pressure is reduced, these fumes clear and the surface of the melt is disturbed by large numbers of small bursting bubbles, which are believed to be caused mainly by hydrogen evolution. As the pressure is reduced to the millimetre region, much larger bubbles occur and the level of the melt increases considerably in height; the occurrence of the bubbles at this stage is thought to be the starting of the carbon–oxygen reaction. The 15-min cycle does not allow this reaction to be completed, but in this case the improvement required does not necessitate prolonging the process time to obtain better refinement. At the end of the degassing period the main vacuum valve is closed and air is admitted to the chamber to atmospheric pressure. The temperature of the metal is quickly adjusted and the metal tapped. Experience has shown that air can be admitted directly to the furnace and that there is no need to admit argon, thus giving a considerable saving in operating cost. A complete operating cycle for the processing of 15 cwt of metal is usually in the region of 35–45 min with a total power consumption of 130 kW/h. An outstanding feature of this furnace is its simplicity of operation; controls are few and the process can be easily controlled by the average melter without technical supervision. Charging and tapping of the furnace can all be carried out by normal foundry personnel. In addition, very little maintenance is required to keep the unit in production.

Preliminary results

It is obvious from the short time cycle that one degassing unit can be used in conjunction with several air-melting furnaces whose sole job it is to supply the liquid charge for the degassing furnace. Of the first 100 heats to be treated by the I.D. process, results show that many of the metallurgical advantages obtained by conventional vacuum-induction melting can be achieved by the simpler process which increases the melting cost only by a matter of 30–40%. A summary of typical results obtained by the 15-min degassing treatment of a heat of 18–8 Cr–Ni steel is as follows:

(i) Reduction in hydrogen content from 17 to 3 ml/per 100 g
(ii) Complete removal of lead
(iii) Reduction of carbon (proving the presence of carbon–oxygen reaction with subsequent decrease in oxygen content): typical figures show a reduction from 0·19% to 0·13%C and 0·06% to 0·03%C
(iv) The ability to produce first-class metal from air-melted heats of 100% scrap, such as oily turnings
(v) Improvement in ductility
(vi) Increased yield of machined castings following a reduction in the rejection rate due to non-metallic inclusions.

These results clearly indicate that the I.D. process can contribute greatly to the metallurgical industry in providing metal with many of the advantages of vacuum-induction melting at a relatively small cost.

Induction degassing developments

The principle obviously lends itself to the construction of furnaces of considerably greater capacity and for the treatment of more complicated alloys, where a higher degree of refinement is required by operating at pressures lower than 0·5 mm Hg. For example, if reactive additions are to be made to an alloy, the full benefit may be lost if the addition is made at the air-melting stage. However, a furnace for operating the I.D. process may be fitted internally with a charging mechanism that enables the reactive alloying elements, such as titanium and aluminium, to be made to the melt after completion of the degassing process and whilst the melt is still under vacuum. As the properties of a specific alloy becomes more stringent, the necessity for the casting of ingots under

vacuum becomes apparent. Thus, a furnace is required which has all the facilities of a high-vacuum induction furnace, but which can be more economically operated by charging a furnace with a basic liquid melt, leaving the alloying and ingot-casting operations to be carried out under vacuum when the refining process has been completed. The increased melting cost due to vacuum treatment demands equipment that is robust, simple in operation, simple in design to reduce maintenance, and, above all, of a form that does not require drastic changes in foundry practice.

Figures 8 and 9 illustrate two methods of carrying out the I.D. process followed by the vacuum casting of multiple ingots. Both methods employ a two-chamber process, the casting chamber working on a similar principle in both cases. The principle of using two chambers leads to a reduction in the total volume to be evacuated and also enables the moulds to be handled with comparative simplicity. An added attraction is the fact that the induction degassing process may be carried out in the furnace chamber; if vacuum casting into ingots is not desired, the metal may be transferred at atmospheric pressure to a ladle for subsequent casting in other ways, e.g. centrifugal spinning.

The moulds are carried on a cradle which is lowered by a crane on to a turntable contained in a vacuum casting chamber. This chamber is mounted on a bogey which runs on rails to and from the casting position. When in position beneath the lid of the casting chamber, the rail section is lifted and the casting chamber sealed to the lid. Individual tundishes may be used on each mould or a common tundish may be used in the lid of the casting chamber. The induction degassing process by the first method (Fig. 8) is carried out in an induction furnace capable of being lip-axis-tilted in a stationary vertical chamber large enough to allow clearance of the tilting assembly. High-frequency power is conveyed to the furnace assembly via a co-axial seal. The vacuum chamber includes the necessary charging devices and temperature measurement pyrometers, all of which may be operated whilst the molten charge is under vacuum.

The main vacuum chamber and the casting chamber are interconnected by a large-diameter pipe which contains a refractory runner for conveying the liquid metal to the ingot moulds during casting. Immediately the casting operation is completed the vacuum is broken, the lid is removed from the main vacuum chamber and the crucible recharged with liquid metal, the necessary alloy additions are made to the charges, and the chamber is closed. During this period the casting chamber is lowered on its rail track and replaced with a new cradle containing fresh moulds already in position. At this stage the process is repeated.

Processing and casting in this way avoids the use of complicated ingot-mould locks and ensures a quick turnround between each processing cycle. However, because the melting assembly is tilted within the stationary tank, the size of this tank is considerably larger than the type shown in Fig. 5 for the simple induction degassing process.

Figure 9 shows an alternative way of carrying out the same process using a similar type of mould

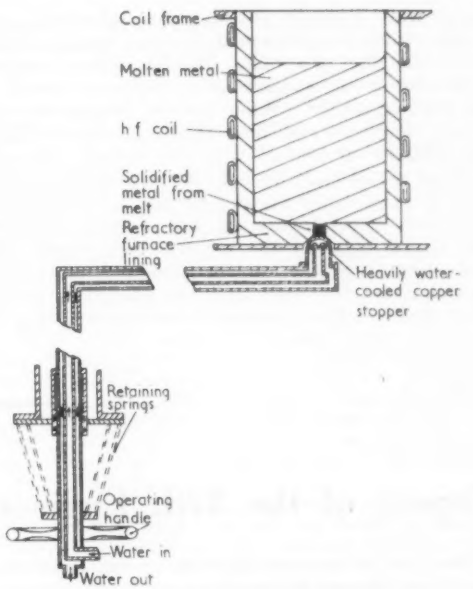


Fig. 11—Bottom-pour mechanism

chamber, but in this case working in conjunction with a tilting tank fitted with a stationary magnetically shielded melting assembly. Although this arrangement has many advantages, especially in the charging of the furnace, and a considerably lower capital expense for the initial equipment, during casting the molten metal has to be conveyed by a runner which bends through right-angles so that the metal may be transferred to the casting chamber along the axis of tilt of the main vacuum chamber. The runner in this case would require to be heated, one method being the use of electrically heated graphite rods, but a more serious restriction is the washing of the runner due to the right-angle bend.

As the demand for vacuum melting and casting increases there will no doubt be a corresponding demand for improved methods of melting and casting with a particular view to simplicity and improved ingot yield. Much of the complexity of a vacuum furnace centres on the necessity of carrying out a lip-pouring operation, and a greater simplicity from the vacuum engineering viewpoint can be realized by the use of a reliable bottom-pouring crucible technique. Past experience has shown that developments made for a specific requirement in one industry can often be used with advantage in other industries. An illustration of this is the possibility of utilizing a bottom-pouring proving technique developed for uranium melting for large vacuum-induction furnaces in the special alloy industry. The furnace shown in in Fig. 10 was built recently for the Australian Atomic Energy Authority, and a new bottom-pouring method was developed for the casting of 200 g of uranium. The bottom-pouring method developed has many unique features which may well make its use practicable for other methods. The mechanism shown in Fig. 11 consists of an arm capable of vertical movement and also of swinging in a horizontal plane. This arm

carries water pipes for cooling a hemispherical copper block, which is positioned in the pouring orifice before the start of a melt. The hemisphere needs to make only a line contact on the bottom chamfer of the pouring orifice. When melting begins, the first liquid metal to run into this orifice is solidified immediately on contact with the stopper; the solid block of metal built up is kept solid throughout the melt by the water cooling supply to the stopper. Immediately before casting, the stopper is lowered and swung clear of the pouring orifice and, after a short interval, the stopper is melted out by conduction from the melt and the charge is poured. Immediately after pouring, the stopper may be immediately replaced, no regrinding is necessary and, owing to the method of sealing, the sealing face remains clean during the pouring operation. This method enables the crucible to be recharged quickly and safely without fear of mis-running. It is not possible by this method to pour the melt in stages, and so there are obvious difficulties if multiple ingot-mould casting is desired. However, an ideal future solution to this problem would be the incorporation of a continuous ingot-casting device operating in vacuum below the stationary melting assembly. In this way one long ingot could be produced of very high yield, as the normal end losses in multiple ingots are reduced to the losses of one ingot alone.

Report of the 37th Engineers Group Meeting

The Thirty-Seventh Meeting of the Iron and Steel Engineers Group of The Iron and Steel Institute was held at Blossoms Hotel, Chester, on Tuesday and Thursday, 14th and 16th October, 1958.

The Chair at both sessions was occupied by Mr F. B. George, Chairman of the Group. The Joint Ablett Prize for 1957 was presented to Mr C. E. H. Morris and Mr N. Dale (both of the Steel Company of Wales, Ltd) for their paper on " Planning the conversion of a high-lift slabbing mill to a universal mill", which was published in the April, 1957 issue of the *Journal* (vol. 185, pp. 532–552). Discussions at both sessions are given below.

Discussion on devices and developments in engineering psychology

This discussion was based on a paper by Mr C. B. Gibbs, entitled **" Devices and developments in engineering psychology,"** which appeared in the October, 1958 issue of the *Journal* (vol. 190, pp. 201–204).

Mr **C. B. Gibbs** (M.R.C.) presented the paper. An introduction by Mr Gibbs to his paper, which is relevant to the discussion, is given below.

I very much welcomed an invitation to be as provocative as possible in introducing my paper because I strongly believe that considerable cross-fertilization between the physical and biological sciences is necessary for our progress, and indeed survival.

My problem is to present facts and arguments in limited time, which will leave no remaining doubt of the wisdom of obtaining sound data on human performance whenever a man–machine system is designed. This may seem too obvious to be worth stating to engineers, who make such extensive use of the physical sciences and base their work on the scientific approach. But in fact very little is being done in British industry as a whole, to apply biological data which are relevant to machine design. Large-scale scientific studies of this nature were pioneered in the UK, but we are falling far behind the USA in using the findings. As one example, the large US aviation firms often employ from 10 to 30 ' human factor ' engineers when designing their aircraft. I know of no similar appointment in the whole of the British aircraft industry. There are already indications that this might have a serious effect on the sale of our products despite their excellent mechanical features.

A large part of my time is spent in criticizing machines which are more or less badly designed for human use, although data and techniques are available which could improve them. Still more time is spent in considering speculative theories of the action of the most complicated machine on earth, the human brain. These are written for the most part by biologists, whose training in mechanical principles is slight. The basic reason for this unhappy state of affairs is an educational system which forces specialization at an unduly early age. All too frequently, engineers lack knowledge of quite elementary biological facts which are relevant to their work.

I quoted in my paper the case of a complicated machine with development costs in the region of three million pounds. The design first proposed would have taken the operator well outside the limits of human response time, although these have been known since 1863. I assured the firm that although the proposed mechanical design was excellent, one formidable difficulty would remain if they used it. This would be to design and produce the entirely new kind of human being who would be required to use it, because the present type certainly could not cope. Later developments were more satisfactory. Comparatively cheap devices were produced to simulate the critical points of operational difficulty without the vast expense of producing the actual machine. This permitted comparisons of several alternative mechanical arrangements to find the best solution. But valid comparisons can only be made if the factor of human skill is equated for all. I was very concerned to find that the engineers were not aware of the basic phenomena of skill which have to be controlled, although these have been the subject of scientific investigation for well over 150 years. A second class of fault is that the designers of machines commonly do not have to use them. This underlies the vast difference in comfort, safety, and

convenience between the usual car and lorry, and there are many other examples.

A third factor is that complex machines are often designed by teams of specialist engineers so that it is rather easy to lose sight of their overall function of serving man. The classical example of this kind of fault was a fighter aircraft of excellent mechanical design. But its overall usefulness was somewhat reduced by the inability of pilots of normal stature to get into the cockpit.

Fourth, careful tests have shown that it is a definite handicap to have been trained in the appropriate use of a specific tool, when there is a need to use it for a different purpose. Custom and tradition die hard, and all too often decisions on human performance are taken on the bases of individual opinion, experience, and intuition. The methods serve if no better can be found, but we are now in an era when the men in industry can be treated on the bases of controlled tests and measurements, which already apply to the other two factors, the machines and the money in industry. These are the basic faults as I see them, and I suggest that the remedy is simple. We need more engineers who will help in serious studies of human behaviour, and more biologists who will study engineering, to obtain the cross fertilization which is so important.

I will end on a note of caution yet of hope. We need caution because the human brain is infinitely more complicated than anything invented by man, and its study is correspondingly more difficult. We have few generalizations and less mathematics to offer at the present time. The subject cannot be taught by a few papers and conferences.

The hopeful note is that there have been tremendous advances in all directions in recent years. The consequences of human errors are rapidly increasing, whether we consider the control of large banks of machines, and atomic power plants; or the accidental dropping of bombs by pilots.

To progress or even survive in such conditions we must know more about the working of the brain, even if this entails learning less about machines. I am confident therefore that the subject will attract in increasing numbers the kind of people it needs and deserves.

Dr **L. N. Bramley** (BISRA): The first paragraph in Mr Gibbs' paper gives more credit to the USA than I can agree with. I have recently returned from a tour of the US steel industry, and can assure the meeting that the science of ergonomics there has hardly started. I know that much work is being done in the US aircraft industry, but the foundations of that work were laid in the Royal Aircraft Establishment before 1914.

Mr Gibbs raises the very important subject of displays and mimic diagrams. In the early days we had displays which were elaborate, but not functional. From them we have developed more functional representations of the things we wished to display, and we have now reached the stage when we can go wrong by making them too functional. Display systems are extremely expensive, but because they are so essential full use must be made of ergonomic principles and in many cases the mimic diagrams can be replaced by much simpler equipment.

On the third page of the paper there is a point with which I disagree. Mr Gibbs says: " The less often a signal for action occurs, the less likely it is to be noticed when it does occur." I do not think that that is correct. It should be qualified by saying that if a signal is made it must be made distinctive; if it is seldom made and is missed then there is something wrong with the signal. Mr Gibbs also says: " The problem of maintaining the vigilance of the operator can usually be met by providing him with a good deal of ancillary work." I emphatically disagree. His remarks would not be applicable to the bridge of a ship steaming at full speed with the observer watching the display on the cathode-ray screen, and other instances could be cited.

He also says that " Experiments have shown a definite and substantial gain in accuracy when one lever of the joystick-type controls movement in two dimensions . . ." I should like evidence of this. BISRA are beginning to study joysticks, and so far have found little evidence that joysticks are better than two controls. We very much need this evidence, to convince operators and executives that joysticks are as good as they are said to be.

Can Mr Gibbs give some quantitative evidence that " varying conditions can be evaluated in terms of operator efficiency . . . " ? We have experienced difficulty in evaluating operator efficiency in this way.

There would appear to be something wrong with Mr Gibbs' statement that if an operator is using only one key he will take about 0·2 s and if he is using two keys he will take 0·3 s to react, " with corresponding logarithmic increases for higher levels of choice." I suggest that if this logarithmic increase is true it would take a lot longer than usual to play " The Rustle of Spring " on the piano !

Mr **Gibbs**: I feel rather guilty about being provocative about applications of ergonomics in the UK as compared with the USA, since our iron and steel industry is doing a first-class job. But comparisons are far less favourable in most industries, for example the aircraft work was pioneered here, but in the USA they are continuing and applying the studies on a vastly larger scale.

Dr Bramley questions my statement that the less often a signal arises, the less likely it is to be seen. This effect was found in fact during vigilance studies on radar operation and it occurs particularly when the man works in isolation with little outside stimulation. Vigilance is greatly reduced if no signals occur for 15 min, but he remains alert for much longer periods if signals occur frequently, or if extraneous stimulation is provided.

His question about controls illustrates the important point that we must be very cautious in interpreting experimental results, and applying them too widely outside their proper context. Our tests for the Royal Navy studied three different arrangements of controls for tracking aircraft. The worst arrangement used two men, one tracking in azimuth and the other in elevation, both using one-dimensional levers. It was much better to use only one man with divided controls, so that one hand lever controlled in elevation and the other in azimuth. But there was a further large gain of about 60% when one man used a two dimensional joystick, so that one hand could control both planes.

More recent experiments have studied a complex task of tracking, and also steering, an object with independent motion. The arrangement first proposed was based upon an argument which at first sight looked like commonsense ' the less you give a man to do, the better he will do it.' But tests confirmed the previous finding, and the simple expedient of halving the crew first proposed, doubled the efficiency of the man–machine system.

Dr Bramley mentions the difficulty of evaluating operator efficiency by controlled tests, in which the operating conditions are systematically varied. There is no easy way out of these difficulties, since the behaviour of machines and men are both complicated subjects which require extensive study. The required knowledge cannot be communicated at a few conferences of this kind or by simple text books. An example of the approach is some recent experiments in which the variables were the sensitivity or gear ratio linking the control and display, and the mechanical lags of the machine response. A graph of errors against different

sensitivities gave a U-shaped curve with an optimal sensitivity, in some conditions of lag. This optimum was so critical that a 10% departure from it roughly doubled the errors, with long time lags.

Dr Bramley doubts my statement that reaction time increases logarithmically according to the number of alternative responses which may be required, and have to be held in readiness. He supports his criticism by saying that pianists could not play as fast as they do if this were the case. This point is a good example of the difficulty of the subject, and of communication, since we are obviously talking about two different situations.

Reaction-time experiments usually present a signal which is unexpected, in the sense that the operator cannot anticipate the exact instant of its occurrence, or predict the response which will be required. This is very different from the situation in piano-playing, typing, Morse-signalling, etc., where long practice enables a man to release whole patterns of movement such as arpeggios, to a signal which is a whole visual pattern of printed notes. Where such grouping occurs as a result of long learning, the detailed information is largely redundant. I find it very interesting that although reaction-time experiments have a long history of over 100 years, it has only recently been realized that these and some high level skills can be linked by the mathematics of the communication engineer, and the laws of thermo-dynamics.

I would agree with Kelvin that "knowledge which can only be expressed in words is of a meagre and unsatisfying kind," and this cross-fertilization between engineers, mathematicians, and biologists is one of the most hopeful of modern developments.

Mr **R. L. Willott** (J. Summers and Sons, Ltd): I do not think that Mr Gibbs was consistent in his opening remarks. He complained that some US aircraft firms had from 10 to 30 experts. He had special praise for them, referring to them as specialists, and then went on to say that the right answer was cross-fertilization. Does Mr Gibbs feel that ergonomics is a subject which should be taught in the universities as part of the engineering curriculum, or is it a specialized subject to be taken separately in later years by trained engineers eventually specializing in ergonomics?

Mr **Gibbs**: I do not think I am being inconsistent in saying that specialists are required as soon as we can train them, but a lot can be done immediately by cross-fertilization and talking about human factors to engineers. Even a smattering of the subject is better than nothing at all, and a great deal could be done at the level of common-sense were more attention given to the human factor.

Training in the subject is rather casual at present in the UK, but it can be obtained. G.E.C. asked for advice on the new atomic power stations and it was clear that the problems justified whole-time specialists. I suggested that one of their people should work with me initially to become acquainted with some of the literature and methodology, and later specialize in ergonomics.

My own initial training was in engineering, but I later took a degree in psychology. There is a real need for people with advanced training in both subjects, and I am sure that our universities will provide it sooner or later. This kind of graduate and post-graduate training is already available in USA.

Mr **Willott**: One definitely wants the man to be purely a specialist, but in the first instance he should have an engineering training and background. One does not want engineers fiddling about in a minor way with ergonomics; one wants, for want of a better word, experts.

Mr **Gibbs**: There is a need for all levels of training. The obvious things which are so rarely done, could be done without special training, such as making simulators in advance of design, and ensuring that designers use their products for some appreciable period.

At the other extreme we need pure research people and consultants. There is a good consulting firm in USA with an annual turnover of about a million dollars, and it is a serious matter that they are attracting some of our best people by offering better prospects.

Miss **I. M. Slade**, M.B.E. (BISRA): DSIR is at the moment discussing this problem with the engineering institutions and various other bodies, and has agreed that two types of training are needed, one for specialists in ergonomics and one for engineers in general, so that they will realize the problems that exist. In many cases the people concerned do not realize that problems exist, and that is why these things have not been thought of.

Mr **R. W. Davis** (John Summers and Sons, Ltd): Mr Gibbs made the point that one of the biggest obstacles to the successful application of any new technique is habit and custom. Habit and custom are the most important part of the accumulated skill of the average engineering tradesman and the apprentice's training is largely spent in developing the habits and customs of his trade. As a journeyman, he goes on acquiring more habits for the rest of his life. In most works there is a complete range of ages; each with its own habits. The young man has a great deal of the habits and customs of the older man because he has acquired them from him. If we try to introduce new habits at what stage do we attempt it in order to give industry the greatest possible advantage from the men who have to use them?

I can imagine that if we tried to change the techniques of a turner who had been at the machine for perhaps 30 years, and teach him new ones we should reduce his efficiency for the remainder of his active life, because he would be struggling with a machine that he did not understand. At what stage in a man's working life does it become impracticable to alter well established methods of work?

Mr **Gibbs**: No general answer is possible, and each case must be considered on its merits. But the tendency to cling to old habits, called perseveration, usually increases after the age of 25, with some exceptions.

A great deal can be done by proper training, to reduce the tendency to perseverate. There is an excellent book called, "Productive thinking" by Wertheimer. This shows that a flexible mental attitude can be developed by teaching principles, rather than by giving rote training in specific and rigid techniques.

A famous illustration of the blinding effects of habit and custom is the typewriter keyboard. An ergonomist produced a new design, based upon an analysis of the English language. This placed the keys most frequently used under the strongest finger, and relegated others to the weaker. They found a considerable increase in the efficiency of typists trained on the new keyboard, although typists already trained had an initial handicap.

It is perhaps more interesting that the question arose of why such an inefficient arrangement had been selected in the first case. The story is that the typewriter was invented by a former compositor, who took over the printer's typecase with which he was familiar. This dated back to Caxton, and although it was inefficient for printing English, it was excellent for printing Latin, which had been its original purpose.

Thus many things are done, not because they are efficient, but because they have always been done that way. To some extent, all improvements rest upon solutions to the problems of education and retraining; and ergonomics is no exception to the general rule.

Discussion on the ergonomic aspects of the design of cranes and master controllers

This discussion was based on the following papers (dates of publication in the *Journal* are in parentheses):

> **"The ergonomic aspects of the design of cranes,"** by *R. G. Sell* (1958, vol. 190, pp. 171–177).
>
> **"Ergonomic investigations into the design of master controllers,"** by *A. Box* and *R. G. Sell* (1958, vol. 190, pp. 178–187).

Mr **J. H. Groocock** (Steel Company of Wales, Ltd): The authors have made a valuable contribution to a sadly neglected aspect of crane design.

The first paper defines ergonomics as the process of "fitting the job to the man" as opposed to "fitting the man to the job." I suppose that crane drivers are among the most conservative of plant operators: I well remember the struggle we had at Port Talbot to wean them away from drum controllers! It was a slow process, but now they would never think of returning to the sort of arrangement illustrated in Fig. 1 (of the first paper).

I endorse the author's remarks about making the driver as comfortable as possible in his job, and also his ideas on possible methods to achieve the best results. But I should like to say something, also, for the maintenance men—particularly with respect to heavy duty cranes operating in intense heat. If the cranes have contactor rooms, it is not usual to refrigerate them as is the case with the driver's cab, and indeed, to do so would mean having to find room for extra bulky plant where space is at a premium. Nor is it always possible to put these rooms well away from the source of heat.

When the driver's cab cooling plant breaks down, he walks off the crane, but the maintenance electricians are expected to attend to breakdowns often in conditions of extreme temperature. This aspect needs more attention.

I think we are all agreed that crane limits are essential and that good maintenance is even more important. Where operations take place in areas of restricted height, the limits are bound to have a severe duty. Even so, some drivers make more use of the limits than they should, and the remedy here is again partly a matter of education. A good training scheme for crane drivers is of very great benefit.

With completely sealed cabs, communications become difficult. Our experience is that there are applications where carrier frequency installations, i.e. the injection of signals into the main downshop conductors, are not only desirable but essential.

We have used this method with outstanding success in our OH shop at Abbey, and we are presently installing similar equipment for communications at our wharf, between the ships and the drivers of the ore unloaders, whose cabs are about 60 ft above the ships' holds.

We fitted up one crane in our scrap-box filling bay, with BISRA/SW controllers, but we have abandoned them for two reasons, (*a*) they are too bulky, and (*b*) maintenance was difficult and excessive.

These were replaced by smaller joystick controllers. The outfit consists of two single joysticks for the hoists, and a dual joystick for XT/L.T. control. They have been operating for two years and the drivers are reasonably satisfied.

We also have joysticks working on one 135-ton ladle crane. There is a single joystick for long travel, and two single joysticks in the same case, for the cross-travel motions. The latter are three-notch controllers, but the drivers hate them so much that we are going to replace them with the four-notch type. In general, our cranes are arranged with five notches in each direction for hoisting and four notches for XT/L.T. control.

Although five or six steps of acceleration are used, four notches are usually adequate for travel control, the additional accelerating steps being brought in automatically under I.T.L.

We doubt the feasibility of accepting less than four notches, as I have already mentioned, we have tried it on a ladle crane and are about to abandon it, but our experience indicates that we do not require more than four notches.

A couple of years ago, we introduced joystick controllers on a number of other cranes, e.g. slab yard, roll shop, pickle bay, etc. They were in fact the same make and type as are in use now on the melting shop cranes already mentioned.

We had strong representation by the unions concerned, who demanded their removal on the grounds that: (*a*) it was dangerous to have joysticks on some cranes and not on others, (*b*) the state of the controls could not be seen immediately and that this could cause confusion, (*c*) positive and independent operation of each motion was difficult.

It was true that registering was not so positive as with the master controllers, but it was really a question of practice. However, events moved too quickly and we had to take them out.

Thus, some education and propaganda are needed when introducing new forms of control equipment to most operators, and certainly to crane drivers. The problem is not made any easier when drivers are switched from one type of control to another in the normal course of their duties.

I must congratulate the authors of these two papers for tackling a really difficult problem in a practical and business-like manner. I look forward particularly to further research into 'Physical Conditions of Work'.

Mr **Sell:** We would agree that in theory joysticks are of value because they can combine two motions into one so that the man does not have to take his hand from one controller to the other. There is a difficulty, however, that one can inadvertently get in the first notch of the wrong motion, i.e. if controlling the long travel there is a tendency to slip into the first notch of the cross travel. They have another difficulty in that if it is required to get into the maximum speed in both directions, a sort of zigzag motion is necessary. We have not yet started investigating the design of joysticks in the laboratory, but it would seem that they will need a fairly smooth and light feel with an extra-positive location in the off position for each motion; this would help to overcome the two drawbacks already mentioned.

If a controller is fitted with three notches, care should be taken to ensure that the crane moves whether loaded or unloaded on the first notch, as if it does not this means that the controller has only two notches. This is a condition we would not recommend.

Mr **A. G. Westmoreland** (Butterley Co. Ltd): The paper on master controllers deals with various experiments to obtain basic data on foot controllers and hand controllers, and the findings and recommendations will be of interest to any designers looking for guidance in this sphere. I certainly agree with the statement that after establishing ergonomic requirements a great amount of engineering ingenuity and development work is required to satisfy them. I would add that satisfying these requirements does not mean that customers will be prepared to accept, or manufacturers to comply.

During the past years the use of BISRA/SW type controllers has steadily increased, and now that they are placed at the back of the cabin and operated remotely

with rods, the previous difficulty with regard to vision for a seated driver has been overcome.

The SW controllers were followed some four years ago by joystick seat units, and many of these are now in use and are proving highly satisfactory, especially when provision is made for the driver to have a change of position. There is, however, a certain reluctance among users who have standardized upon the SW controllers to change over now to the newer seat units, no matter how superior they may be. Both of these types of master controllers have proved very successful and it is now most desirable that they should be finalized in the interests of standardization and maintenance. Any attempt to introduce further types of controllers at present would bring confusion to both makers and users.

Apart from the undesirability of manufacturing and maintaining a large variety of controllers, one must always consider the human element and spare a thought for the driver who may be transferred frequently from one crane to another.

The paper states that a considerable period of training is necessary to obtain the required skill for successfully operating foot controls, and this alone would seriously restrict their use.

No recommendations are made regarding foot pedals for operating hydraulic brakes, and makers continue to supply old-type pedals requiring about 10 in. of movement which is unsuitable for seated drivers.

Finally, the illustrations give some indication of the serious interference of foot controllers with the downward vision required when seated, and although the controllers could be moved to the back of the seat, the pedals and their supporting attachments would still form a most serious obstruction.

As for Mr Sell's first paper, a lot of his material is quite well known to us, and I think that we are in general agreement with the various points which he brings to our attention. For some years we have been dealing with new types of seats and controllers and designing the new cabins necessary for their use. Cabins with semi-circular fronts have now been superseded by cabins with flat windows and sloping lower glass, which give good downward vision.

Following the emphasis on anatomical chairs and anthropometric seats, it is good to note that the need for standing up is mentioned in the paper, coupled with provision for the controllers to be used in either position. It was not uncommon to hear of drivers with these comfortable chairs craving for the luxury of a stand-up, to rest themselves during long spells of duty.

This paper also says that grills can be fitted on the outside of the glass, but we prefer to fit suitably designed foot grills on the inside, as shown in Fig. 3. This gives the driver a feeling of security and also protects the glass from becoming badly scratched and rendered opaque.

I was surprised at some of the remarks about aids to driving. Many will disagree with the suggestion that the hoist can be allowed to look after itself and park itself with the limit switch, particularly when the headroom is limited. This would call for a second limit switch, and would reduce working headroom. Anything which may lead to careless or lazy driving should be strongly discouraged, and non-resetting limit switches are frequently advocated as a deterrent to such bad practices.

Mr Sell: Several difficulties arise in connection with the grouped seat-control unit. Rarely does this unit incorporate a seat of the kind that we recommend and very often the controls are not placed in the best positions. Once these units have been built it is also very difficult to change the position of the controllers. As we all know, different works have their own ideas and like to move the controllers around.

I agree that foot controllers tend to block visibility, but we think that they will be of more value in places like rolling mills than on cranes. The controllers used in the laboratory were experimental and were much bigger than would be necessary in a production model.

I agree that the hydraulic foot brakes manufactured at present are much too large and very awkward to install satisfactorily in a crane.

When I mentioned limit switches, I was deliberately trying to be provocative. I wanted people to think about their use, because on some multi-motion cranes, especially new ones installed in old shops, the hoist may normally have to work very close to its limit and if one puts in an efficient limit switch it gives the driver a chance to concentrate on his other motions.

Mr J. Bunyan (Allen West and Co. Ltd): Ergonomic investigations of a kind have been made by manufacturers and users alike for a number of years, but these have been very rudimentary in nature and limited in their scope, and frequently leave too much room for personal opinion. It is obvious that technical data derived from intensive investigations by properly qualified people who are either in or closely associated with the user's industry must lead to the production of a better tool for the job, particularly if appropriate test apparatus and logical procedures are applied.

Ever since drum controllers were first used the question of 'feel' has caused more headaches than any other aspect of design. Many combinations of roller diameter, notch width, shape, depth, and spring loading have been used to provide controllers with acceptable feel.

In view of all this I am surprised that in the case of the hand-operated master controller described in this paper, only one size of roller, and shape of notch, and two alternative spring pressures were used in the main experiment, even though these were the outcome of preliminary investigations on 243 settings. It would appear that the test controller used in these preliminary investigations incorporated cam-operated snap-action microswitches which require very little effort to operate. This set-up is no doubt acceptable from the viewpoint of ergonomics, but it does lose sight of the fact that one of the functions of notching on the usual drum-type or cam-operated master controller is to ensure that the contacts are not left in an intermediate position where they can arc and splutter. This imposes more loading on the notching mechanism than is necessary for mere location. Furthermore, when varying numbers of contacts have to be operated, on different notches, the loading varies from notch to notch.

If this ergonomic investigation is aimed at getting the best out of master controllers of existing types then I submit that more consideration should be given to the question of notching. On the other hand, if the purpose of this investigation is to find the data for the ideal master controller, solely from the viewpoint of ergonomics, then my remarks concerning notching do not altogether apply. It does mean, however, that the contacts must be easily operated so as not to influence the notch location of the controller. Such contact mechanisms are necessarily more complicated than the ring-and-finger or plain cam-operated types. Furthermore, they must be small and compact to keep down the overall dimensions of the controller. This may not be to the liking of some steelworks engineers, but provided the mechanism is properly designed for its function, there is no reason why it should not give excellent service.

As for the conclusions drawn from the experiments on the hand-operated master controllers, it would be interesting to know how the three different types of 'feel' compared with each other after the provision of extra off-position location.

Reference has been made to the great desirability of reducing the size of master controllers to a minimum so as to make possible a compact layout of controls arranged for easy and convenient operation. In this connection, I should like to sound a note of warning. Master controllers might be made too small for the duty they have to perform. This limitation in minimum size is not due to any considerations of design but is imposed by the effects of chemical action. It has been found that for any given volume of enclosing case there is a maximum permissible figure of watts-seconds of arcing energy per second. If the duty required of the master controller is so heavy that the arcing energy exceeds this critical figure, a series of chemical reactions takes place. First, ozone is formed, and if this is not allowed to disperse nitrous oxide results. In the presence of moisture this becomes acid and corrodes the interior of the enclosing case and its contents so that eventually the operation of the master controller is destroyed.

I know of only two ways of overcoming this trouble: (*a*) the provision of a small amount of ventilation, (this is undesirable as it allows ingress of dust some of which might be metallic); (*b*) to increase the size of the enclosing case. Arc quenching devices are not always provided but when they are they should be in the contactor panel.

The ergonomics research section of BISRA has put in a very considerable amount of time and thought to the factors which lead to the provision of master controllers best suited to the requirements of the steel industry. On the other hand, steelworks engineers responsible for the selection, installation, running, and maintenance of plant are inclined to be individualists. Will they abide by the findings of BISRA and accept controllers made in conformity with those findings?

Mr **Sell:** Our investigations were aimed at finding the ideal master controller from the viewpoint of ergonomics and we included in our investigations one controller which had no artificial feel at all. Our full-scale laboratory experiments take a long time to carry out and we have to restrict as far as possible the number of variables considered. We did, in fact, consider two different types of notch design and did not just vary the spring compliances. We can, however, let anyone who is interested have full details of the preliminary experiment in which we graded various combinations of roller size, spring compliance, angle of notch, diameter of peak of the notch, and operating forces, according to their feel characteristics. Extra off-position location had the greatest effect when there was no artificially induced feel, and the least effect when there was a very positive feel.

Mr **Bunyan:** My point was to query the relative merits of the control with no feel and the control with feel when both were provided with extra off-position location.

Mr **Sell:** In all cases a controller with a medium feel was better than one with no feel.

Dr **L. N. Bramley** (BISRA): The experiments we did in BISRA, using microswitches, were perfectly logical. I laid down, in a paper in 1950, the requirement that a master controller's location must be dominated by the locating gear, and that if between two locations it is going to open the control contact there must not be enough resistance to the feel of the controller to add to the locator feel so that the impression is gained that there are twice as many locators. The force required to open the contact must be slight compared with that required to break out of locator points. It was, therefore, strictly logical for us to use microswitches, with a negligible amount of force required to open them.

Mr Bunyan made some important remarks about the amount of energy released when the arc is struck in the contacts. He has supported BISRA steadily through the years and, as a result, we have produced between us a controller which is much smaller than any other controller, and which is undergoing successful tests in a steelworks now. But I do not agree that this master controller of Mr Bunyan's, although much smaller than any other, has reached finality. The watts being controlled by a master controller are extremely low, and the controller is still much too large. If we are to make further progress we must suppress the arcs by means of non-linear resistances, and if some experimental work can be done there is no doubt that the new controller can be reduced to half its present volume.

Discussion on human temperature regulation and the steel industry

This discussion was based on the paper by Dr R. F. Hellon, entitled "**Human temperature regulation and the steel industry,**" which appeared in the October, 1958 issue of the *Journal* (vol. 190, pp. 197–200).

Dr **R. F. Hellon** (M.R.C. Unit, Department of Human Anatomy, University of Oxford) presented the paper.

Dr **W. E. Scott** (Stewarts and Lloyds Ltd): Dr Hellon emphasises the fact that work performance, and therefore production, has been found to be adversely affected by hot surroundings. Is he relying solely on the evidence presented by H. M. Vernon, whose work was done in 1920? We do not find this to be true at Stewarts and Lloyds and have no evidence to the effect that production varies seasonally in hot or cold weather.

The question implied in the speaker's reference to crane drivers operating in hot conditions, "Can anyone say whether there was an increased accident rate or decreased work efficiency in summer, as compared with winter?" is answered by saying that we find no difference.

Thirdly, has Dr Hellon taken note of the attitude of managements in relation to the effect of heat work on the comfort of the worker rather than on his health and safety? My view is that unless we can prove conclusively that increased heat equals decreased production, managements are apt to lag behind in their efforts in this field, bearing in mind the fantastic adaptability of the human body and also the long tradition in the steel industry of the ability of the worker to 'sweat it out' under hot working conditions.

Also of interest was the reference to protection methods, particularly that of reflective suiting. It would seem that the subsequent failure to dissipate metabolic heat will be the main difficulty. With regard to the question of which gives the best results, protective clothing, radiation screening, or both, we would do well to remember the dictum of Sir Thomas Legge: "If you can bring an influence to bear external to the worker, that is, one over which he has no direct control, you will be successful, and if you cannot or do not you will never be wholly successful."

Finally, as a comparatively non-scientifically minded works doctor, I would like to pose this question to Dr Hellon: "Whatever the success of the protective measures he is advocating is there not still a place for careful job selection and placement, plus the intelligent education of new entrants, bearing in mind the tradition existing in the industry?"

Dr **Hellon:** Dr Scott said that we were relying on Dr

Vernon's work, on the effect of hot surroundings on working efficiency. There is no doubt that his evidence was sound, although obtained some while ago, but I think we all know that in very hot maintenance work (not necessarily production work) there are twice the number of men needed on the job, for it cannot be done any other way. It is physically impossible for men to work in such conditions for more than half the time under normal conditions. This has been formalized by agreement between the unions and the managements in most cases.

With regard to heat not affecting crane drivers, that is probably a valid point. The experiments done only show a temperature effect when a man's performance at tracking a crane is pushed to the limit.

Mr **C. B. Gibbs** (Medical Research Council) : In Morse receiving and sending there is a slow deterioration as temperature is increased within a certain range, and then a virtual breakdown in efficiency at a critical level; but tracking skills do not seem as susceptible to temperature effects as mental skills.

Dr **Hellon:** As for the point about management not being concerned about this problem, when there are twice as many men as are needed on a job, I think they should be concerned about it.

Reflective suiting is a double problem. First, one must provide a *durable* reflective surface on the outside of the suit, then once the worker is inside such a suit, the heat he generates himself must be dissipated. The only way to do this is to provide a continuous stream of cool air from outside, and that is one of the things we must build into the suit. If men work under such conditions they must be ventilated. This happens with high-speed aircraft, where the pilots are kept cool in this way, and also in various atomic establishments, where people have to wear completely impermeable suits, but there the problem is not serious because conditions are not so hot.

Lastly, the question of job selection for work in hot surroundings is a very difficult problem. Some people are much more susceptible to heat stress than others, and there are ways of sorting them into susceptible and non-susceptible groups. This is done with great success in the gold mines in South Africa. When native recruits start work there, they are put through a hot-room test to assess their ability to withstand heat.

In addition, there is the problem of acclimatization. These maintenance men do a cold job one week and a hot job the next, and that means that unless they are exposed to heat almost every working day they will never have more than partial acclimatization to those conditions. One loses acclimatization to heat after about a week of not being exposed to hot conditions.

The **Chairman:** In 1926 we provided the men digging slag out of our soaking pits with bamboo helmets, something like the old P.H. gas helmets. These had asbestos covers, the ends of which were tucked into the men's shirts. The helmets were supplied with compressed air and a reducing valve. The men said that this apparatus interfered with their piece work, and they would not wear them.

Has Dr. Hellon heard of men dying from dehydration in a steelworks?

Dr **Hellon :** No. I ask that question whenever I go to any works. Cases of heat collapse are extremely rare.

The **Chairman:** We had a case where the *post mortem* examination alleged that the man had died of dehydration, but it seemed extraordinary to us because he was not working in a very hot place!

Discussion on crane safety

This discussion was based on a report: "**Crane safety in the iron and steel industry**" (a report of a sub-committee of the Accident Prevention Committee of the British Iron and Steel Federation).

Mr **W. M. Larke** (Stewarts and Lloyds Ltd) presented the report.

Mr **R. L. Willott** (John Summers and Sons, Ltd): This very important and excellent report reflects great credit upon Mr Larke and his sub-committee. It acknowledges the many practical difficulties which surround crane operations in steelworks; to us they are everyday factors, but they occupy a very special place in plant operations and call for realistic consideration.

In my view the report is remarkable for the mildness with which it appears to make quite basic recommendations, but after closer study one begins to realize how nicely Mr Larke's committee recognizes that safety does not necessarily result from rigid rules. Rather is it the result of voluntary self-discipline on the part of individuals, self-discipline on the part of unions, teams, sections, and departments, besides self-discipline within the factory as a whole.

Self-discipline must surely be vital since 75% of all present-day accidents occur as a result of involuntary action on the part of individuals knocking against, falling over, tripping, etc. Basically therefore the main question must be one of individual attitude. If that is so, what do we propose to do individually about the report ? For the first time a much-needed publication has been produced setting out clearly and comprehensively the whole field of crane operation, crane maintenance, and crane safety. It does not follow that we agree with every word of it, but if by adopting even one recommendation within our own factory or department we are able to save the life of one man or prevent only one serious accident, then the work of Mr Larke and his committee will have been justified. Some definite policy and organized discussion leading to positive action within our own factories is surely indicated.

In connection with the training of drivers and slingers the report stresses: "The early training given to crane drivers and slingers will affect their performance and attitude of mind throughout their working lives." I agree that early training is vitally important. Should it be left to amateur instructors in individual steel plants, or should something be done to produce the quality of instructor which Mr Larke has impressed upon us by arranging for his initial instruction to be done under more appropriate conditions ? The training section of the BISF at once springs to mind. Since the apparatus necessary to give a crane driver sound basic instruction is expensive, I suggest that if the industry pooled its resources it should be possible to have a first-class instructional staff, using only first-class apparatus, and resulting in a first-class product.

On the question of means of access to cranes, the report says: "Wherever possible stairs are preferable to ladders . . ." That is a gross understatement. Ladders may provide satisfactory means of access to water towers and chimneys, where approach is on rare occasions, and for specific purposes by specific people. To gain access to any crane or crane gantry in steelworks, I suggest that stairways should be a statutory necessity. Vertical ladders cannot be a correct means of approach for greasers, craftsmen, and inspection crews carrying tools and equipment.

The report suggests that long-travel conductors should be placed so that people working on gantries and crane

tracks never come into contact with them. Why not under the roof truss, about 7 or 8 ft from the roof leg? Mr S. A. Lewitt and I agree that this is the right place and in our building extensions we have specified that long-travel conductors should be under the trusses. We already have existing installations which have given satisfactory operation over an extended period.

The subject of lifting tackle is rather a delicate one, and the report could hardly go into the matter in detail. We all know that the old-fashioned sling frequently has wire ends sticking out, resulting in a serious hazard to hands and fingers. Binding and seizing of such splices does not last long in day-to-day steel plant usage. There are on the market alternatives, some with single smooth ferruled ends (as illustrated on p. 39 of the report), and some more complicated ones which are excellent. One embodies a Flemish splice, which is additionally ferruled with single or duplicate collars. What is the attitude of the Factory Department to these slings? What is the attitude of the Crane Safety Report Committee to them? Are all or some of them acceptable, or not? I know that for certain purposes they are acceptable at Lloyds and that a number of firms have adopted them, but as an engineer I am not entirely convinced about some of them. Has not the time come when some appraisal of those new forms of sling could be made available to the industry?

Mr **B. R. Jackson** (Stewarts and Lloyds Ltd): I would like to comment on a method of repairing steel chain and give some illustrations of a few unsatisfactory steel hooks.

Figure *A* shows a photomicrograph of the quenched and tempered structure in steel chain. The weld heat affected zone is largely removed, in both resistance butt welds and flash butt welds, by heat treatment.

Chains of this type are widely used in the iron and steel industry, but a common method of repairing a chain is to use joining links welded by electric resistance flash butt welding or atomic hydrogen and to heat treat each single joining link by electric resistance heating. A normal quenching temperature is aimed at and the link is then quenched into molten salt at 300° C. One would not expect the link to have the same properties as the rest of the quenched and tempered chain. Figure *B* of a weld of a resistance welded link treated in this way

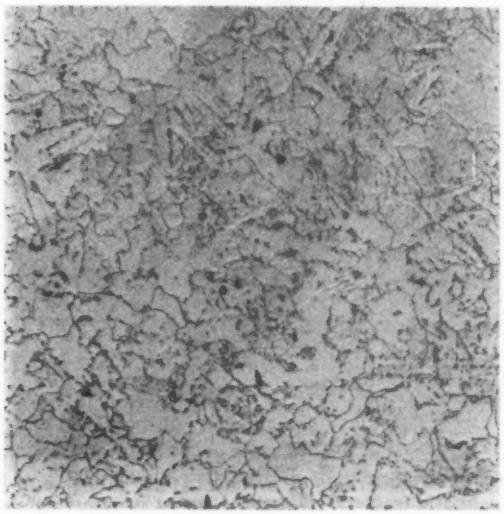


Fig. *A*—Photomicrograph showing structure of a quenched and tempered link × **1 000**

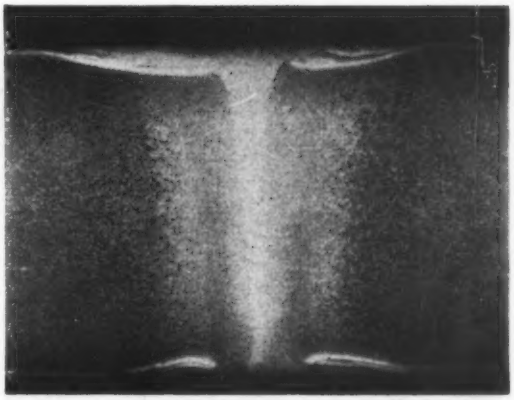


Fig. *B*—Photomicrograph through an electric resistance butt weld, heat treated by a single link reheater unit. Heat treatment has failed to give the weld area a uniform structure × 5½

shows that the heat affected zone in the weld region has not been completely removed, as the heating time in this process is short. Figure *C* is a photomicrograph of the structure; it is much coarser than that of the normal quenched and tempered link.

This method of isothermal heat treatment, as it is called, gives a link with a less satisfactory shock resistance than normally quenched and tempered chain. Clearly, this process requires very careful control in order that the link should have even the same tensile strength as the quenched and tempered links. This method of repair is very widely used, and surely it should be properly investigated and dealt with ultimately in appropriate specifications?

A very important component of a lifting sling is the hook, and not infrequently one hears of hook failures in which the hook breaks with a brittle fracture. Three very important factors are the chemical analysis, the heat treatment of the hook, and its surface condition.

Figure *D* shows a hook which has broken with a brittle fracture. The face of the fracture shows clearly the forging defect from which the break occurred and another forging defect clear of the fracture is also present.

Chemical analysis of this hook shows a carbon content which puts the steel in the spring steel class: 0·636%C, 0·58%Mn, 0·02%Si, 0·033%S, 0·05%P, 0·001–0·005% Al (in solution). Such a high carbon content should obviously never be used in the normalized condition for lifting tackle. Another hook fracture was found to be due to high phosphorus, and the steel was of rimmed quality, which should never be used for a hook. The chemical analysis was 0·065%C, 0·535%Mn, 0·013%Si, 0·064%S, 0·119%P, 0·004%Al (in solution).

Figure *E* shows another hook failure in which the chemical analysis is satisfactory, but the hook surface is crazed with numerous fine fissures. This type of surface breakdown can result from heating the hook for too long in the forge fire or by heating at too high a temperature. Such surface breakdown is naturally very dangerous, but the static load test is unlikely to show it up. Also, examination may fail to reveal such a crazed surface, as the heat-treatment scale may camouflage it. However, the sharp loading of service conditions can easily cause such a hook to break with a brittle fracture.

Figure *F* of a section through one of the arms of a ramshorn hook which had a surface breakdown similar to that shown in Fig. *E* shows that the natural flow of the steel is at right angles to the working surface. This

Fig. *C*—Photomicrograph showing the coarse structure resulting from isothermal heat treatment intended to simulate a normal quenched and tempered structure × 1 000

means that a brittle fracture could take place as a result of a steel segregation of non-metallic inclusions or phosphide banding.

It is obviously very important that the flow of the material should follow the working contour of the hook, and this can only be achieved if the hook is to a large extent forged. British Standard 3017 actually permits the use of a hook which has been flame cut to shape and then finally lightly forged. This light forging will make very little difference to the flow of the material in the region of the working surface.

Shock resistance is very important, and an inherently fine-grained steel with a controlled aluminium content has good impact properties and forges easily.

Suitably quenching and tempering a coarse-grained steel can give very good shock resistance, but with hooks, quenching and tempering is rarely satisfactory, as the large mass of the hook makes an effective quench difficult. This means that all except small hooks must be normalized and in this condition fine-grained steels have better shock resistance than coarse-grained material.

I would like to suggest that a steel of this type, with a carbon content of 0·1%–0·15% be included in the B.S. specifications, as I am sure some users would prefer this fine-grained steel to the specified higher carbon En3 steel, which is not of guaranteed fine-grain size.

Mr **H. Entwistle** (Ministry of Labour and National Service): First of all, Mr Larke referred to the number of accidents in steelworks. For the last 12 years all crane accidents have been analysed and some have been tabled in H.M. Chief Inspector's annual report. How the steel industry comes to be accused of being responsible for one-third or one-fifth of the total I do not know. Buildings and docks are responsible for a great number of crane accidents and the steelworks are not involved in one-fifth, unless you are referring to overhead cranes only; in that event it may be true but it is not the case with crane accidents in general.

Mr **Larke**: It was overhead cranes; I am sorry.

Mr **Entwistle**: There are one or two things in the report upon which I want to comment. First, the greatest number of accidents can be attributed to bad signalling, bad slinging, and bad driving. They are responsible for two-thirds of the total number. The committee has gone a long way towards providing something to work on in this connection. It is suggested that the Sheffield Safety Group's ideas should be adopted. The instructions in the Sheffield Steel Works Safety Handbook have proved very valuable.

One reason for advocating this is that throughout the country different signals are made, and that leads to confusion if a signaller is moved from one place to another. It will be an advantage to have a universal system of signalling.

Mr Sell referred to auditory signals. We do not want them under any circumstances, except " Stop ! ". Signals made by word of mouth lead to mistakes and accidents, and that recommendation has been stressed in this report.

It is a little dangerous to say that a crane driver should be of average intelligence or a little below. If a crane driver gets hold of this report and reads that he will say, " So that is what they think of me." That would be unfortunate.

Two things were said in Mr Sell's paper on the question of controls. In one case he said that remote control by a linkage system could be used. I am afraid that the Inspectorate would oppose linkages; there are too many pins to wear and come out and too many levers to bend. One well known motor-car firm is reverting to the floor type of gear lever rather than the steering column type for that reason.

Mr Sell is right when he says that a lock should be fitted in the neutral position. Mr Bunyan and I discussed this at some length on a previous occasion. If there is a building operation in a works and a mobile crane is lent to the builder then an offence is being committed,

Fig. *D*—Photograph of a hook which failed with a brittle fracture. A forging defect which triggered the break is clearly shown, together with a second forging defect. The carbon content of this hook is far too high

because the lever will not lock in the neutral position.

Mr Westmoreland made a point about the non-self-resetting limit switch. The evidence obtained for the committee showed that Mr Larke is quite right about the misuse of limit switches, that drivers will use them as an automatic knock-off, and we have trouble as a result. There are present two representatives from firms who within recent years have had fatalities as a result of this. If a limit switch is fitted it should not be used as an automatic knock-off; the hoist controller only should be used for arresting the motion even where headroom is limited. It is especially important also that the brakes be maintained. I advocate the non-self-resetting limit switch because it puts the driver to some trouble to reset it, and such inconvenience will discourage misuse. At a Sheffield steelworks all the limit switches are of the non-self-resetting type, and they have suffered no inconvenience as a result.

A modification to Section 24 (7) of the Factories Act, 1937 which Mr Larke mentioned is in the draft of the new Factories Bill and it is proposed to extend its scope. At present if a person is at work on or near the wheel track of an overhead travelling crane and is in such a position as to be hit by the crane it must not come within 20 ft of him. The committee has gone a long way on this question because it has tackled the real issue, which is one of drill and discipline. It is 90% a question of the human element. The man who is usually hurt is the one who goes to do the odd job for the odd moment. If a drill is instituted whereby all men know that if they are going up even only for a couple of seconds they must go through an established routine I have every hope that the system laid down will work. However, I have known bunting, flags, lookouts, whistles, etc. fail to ensure safety within the past 12 years. The only one that has not yet failed is the system devised by the Ford Motor Company and also used by the Vauxhall Motor Company which necessitates electrical isolation and rail stops. Stop blocks might not be, but usually are, used with that system. There has not been one accident reported to the Inspectorate during the last 12 years resulting from the use of stop blocks, but there have been plenty due to their absence.

Mr **J. Baker** (Clyde Crane and Booth Co. Ltd): On the question of hooks, there are many forges today that are forging a slab, burning it to shape, and doing a light amount of forging work. I have resisted this and I hope that buyers of cranes will refuse hooks which are not properly made. It is a scandal that slabs are being called hooks.

Fig. *E*—Photograph of the working surface of the hook close to a brittle fracture. The fracture has resulted from the severe surface breakdown which is clearly shown

Fig. *F*—Photograph of an etched section through one arm of a ramshorn hook showing that the natural flow of the steel is at right-angles to the working surface

Safe load indicators were mentioned. In a relatively short time nearly all crane makers should be able to sell cranes which incorporate a reasonably accurate weighing device, and the question of not knowing what load you are lifting will be a thing of the past.

We have tried out telephonic and other verbal means of communication with the driver and have found them suitable for giving the driver instructions for handling a special load, but not for starting and stopping the crane. Hand signalling is better, even where the slinger on the ground is more than 100 ft from the driver.

The attractiveness of disc brakes for a cranemaker is not because of the point mentioned by Mr Larke but because of the reduced moment of inertia. We shall welcome them when we can develop a decent design, but many difficulties are involved.

When I first read the report I was in agreement with almost everything said in it. Then I had further thoughts on the subject. Since electric cranes became a common tool in steelworks it was questionable what we had done to improve the safety of the cranes. We have fitted in overwinding limit switches! We have totally enclosed the gears so as to prevent a man putting his hand into them, but enclosure increases the maintenance period and as it is always a hazard working on a crane I doubt whether the enclosed gears are really a safety device. They comply, however, with the law, and we have to have them. We have put on coupling guards, which prevent fingers being trapped, but it is difficult to tighten up the coupling bolt. Then we put the guard that Mr Larke showed on his slides, right across the platform on a crane, so that nobody could touch the T-bars. This complies with the requirements of the Factories Act, but it makes an obstruction for workers who want to get at the crab for maintenance purposes. On top of this the weights of cranes have gone up 70%, and in some cases 85%. That is the position reached in a period of 50 years of crane design!

It would not be a bad idea for a small sub-committee to reconsider the matter from first principles. I would like the Factory Inspectors to be represented; we would have to agree to alter some of the requirements specified in the Factories Act so as to enable us to make a crane as it ought to be made.

Mr **R. W. Davis** (John Summers and Sons, Ltd): I felt on reading the report that it gave a very clear guide to avoiding the risks involved in the normal operation of cranes. It is, however, common knowledge that engineers in the steel industry continually complain that cranes are abused as a matter of course and I feel that the principal risks associated with overhead travelling cranes in particular are due to their abnormal use as pieces of engineering equipment. This abnormal use is, in fact, normal in a melting shop or other process department.

If this fact is understood by the users and suppliers of process cranes, the crane is usually designed to withstand the abuse that it must suffer and, being less likely to fail in service, is safer.

No criticism of the operator is necessarily implied in the word 'abuse,' it is the engineers who must be criticized for supplying and accepting a machine not designed for the job. In a recent incident a grabbing crane, hoisting and long-travelling at the same time caused the ropes to angle so badly that the hoist-barrel bearing-cap burst off and fell to the ground. The risk is obvious and might have been avoided by more robust design. It would, of course, certainly have been avoided by better driving. More attention might have been paid to the frequent abnormal crane usage in the steel industry, and the attendant risks to drivers and other personnel which it brings about.

Mr **W. R. Robertson** (Wellman Smith Owen Engineering Corporation Ltd): Mr Davis has put his finger on a very important point.

It is reasonable to assume that crane makers should be given information on this question of abnormal usage and not be told after the crane is put to work "you should have known that we carried out so and so in our shops."

If it involves excessive load dragging, for example, damage to ropes and possibly hoist barrel may result. If prior information is to hand, the crane makers can give the user the tool he requires without incurring additional expense if called on to fit extra gear after the crane is erected.

It was disconcerting to read in the Safety Report and in one of Mr Sell's papers that constant operation on the hoist limit switch was a safe procedure. This is a pernicious practice, although possibly unavoidable when a new crane is installed in an old shop where headroom is not available and consequently the topmost point of lift cannot be obtained without tripping the limit switch every time. The production man does not like this, the night shift decides to disconnect the switch, an overwind results and next morning the crane makers get a frantic 'phone call to the effect that a hoist rope is broken and the snatch block is badly damaged.

With a new crane in a new shop there is generally the necessary headroom for the snatch block to operate unhindered under working conditions.

Mr **H. Rushforth** (Appleby-Frodingham Steel Co.): I should like to endorse Mr Robertson's remarks on the question of control gear clearances. I realize that adequate clearances are a legal necessity, and rightly so, but when one is asked for clearances of 3 ft in front and 3 ft at the rear of panels, whether open-type or enclosed, in addition to the width of the panel itself the dimensions to be accommodated are reaching ridiculous proportions where cranes are concerned.

I feel that control gear makers could do much more than they are doing at present to assist us in this matter. Why, for instance, cannot the internal panel wiring be accommodated at the front of the panel instead of at the back, thereby eliminating one set of clearances.

CORRESPONDENCE

Mr **S. Burrows** (Adamson-Alliance Co. Ltd) wrote: The reference to limit switches in Section X of the report, dealing with New Designs of Cranes and New Construction, is both informative and challenging. The sub-committee recommend that a Palmer-type series switch, with regenerative braking should be fitted, and that operation should be from the hoist gearing.

For some years past the question of limit switch operating gear has received our close attention, and some time ago we introduced a unit of entirely new design. In effect, a sort of free-wheel coupling is fitted to an extension of the barrel shaft, and by means of a planetary pinion, the mechanism becomes locked at the required tripping position, causing the 'coupling' to turn with the barrel shaft and trip the Limit Switch. This type of gear has been successfully used for the operation of small shunt switches and up to the largest Palmer switches, capable of breaking a 200 h.p. circuit. The operation is positive, and the weight on the switch arm is used for re-setting only.

The report also recommends that a second or 'long stop' limit be fitted. The term 'ultimate limit' is sometimes used and this has the advantage of removing all ambiguity. The fitting of another Palmer switch is often ruled out owing to lack of space and increased high cost. In the words of the report however, "Any electrical protection at present devised is unlikely to be effective under all conditions, and consideration should be given to the provision of a mechanical 'safety stop'."

The mechanical safety-limit stop referred to in the report is actually in effect, a very substantial spring buffer mounted on top of the hoist bottom block, and in the event of an overwind, the top plate of the buffer meets a cross beam under the trolley and further hoist travel causes compression of the springs, thus absorbing stored energy of the rotating hoist gears and motor armature. A possible, indeed an obvious, objection to this method is that all braking effort is transmitted by ropes and gearing, greatly reducing the safety factor on these items temporarily. The point of application of brake torque should preferably be as close as possible to the revolving source of energy, i.e. the motor armature and higher speed gears. With this in mind we are at present developing a direct braking system for the ultimate limit. The ascending bottom block, or in the case of a ladle crane, for instance, the beam, will actuate a lever or plunger and positively apply a brake located on the pinion shaft of the hoist gear. Using conventional types of brake, this system would be impracticable, owing to the increased inertia of revolving parts and disproportionate size of brake required. Developments in the aircraft and automobile fields however, have furnished practical proof of the superiority of the disc-type brake in certain situations, and we look forward confidently to a solution of the ultimate-limit brake problem, utilizing the experience gained in a totally different field of engineering.

Mr **Larke** wrote in reply: I was very glad to read Mr Burrows's comments and entirely agree that the long stop limit as suggested does impose considerable loads on the ropes and gearing, but as Mr Burrows points out, some of the shock is absorbed by the spring cushion. I am delighted to see that his company are developing a direct braking system for the ultimate limit, for this is something that has been needed for a long time, and the application of a disc-type brake may well provide the means for a satisfactory solution of the problem.

Joint discussion on the structural design of steelworks cranes and the plane-frame analysis of lattice girders

This discussion was based on the following papers (the dates of publication in the *Journal* are given in parentheses):

"Structural design of steelworks electric overhead travelling cranes," by *D. Buchanan*, B.SC.(ENG.) and *R. G. Tyler*, B.SC.(ENG.), A.M.I.C.E. (1958, vol. 188, pp. 371–388).

"The plane-frame method of analysis for lattice girders," by *R. G. Tyler*, B.SC.(ENG.), A.M.I.C.E. (1958, vol. 190, pp. 187–196).

Mr **D. Buchanan** (BISRA) presented the first paper and Mr **R. G. Tyler** (Hatfield Technical College) the second.

Mr **D. B. Wilson** (Steel Company of Wales Ltd): The authors have obviously treated the whole concept in considerable detail, and the papers are all the more valuable in being based on tests on actual cranes of various types. One notable feature is the low operational stresses achieved in the crane structure. My company recently made time, distance, and maximum velocity tests on a 300-ton ladle crane, and had the operator running the crane at full velocity and then swinging the controller from full forward through zero to full reverse. The tests were done with an empty 90-ton ladle, and correcting for the full load on the crane we found that the maximum deceleration was 1·7 ft/s².

A test on the emergency stop, and tests with the usual methods of braking, i.e. reversing on the first notch on the controller, were also made. These two conditions were roughly of the same order, and the maximum deceleration was about 1 ft/s². It should be pointed out that we are working to too high a specified deceleration value for maximum load.

Another feature of these tests was that certain maximum permissible stresses are allowed, but the maximum stress in the top flange of the girder is a combination of vertical and horizontal forces. To date no crane specification allows for any increase on this permissible stress and some increase should be considered because under the combined vertical and horizontal forces only the extreme edges of the top flange are stressed to the maximum.

The authors state that the values of the BISRA fatigue factor have been co-ordinated with the committee sitting on the revisions to B.S. 153. That committee has now moved forward and its recommendations now permit a higher factor than at present allowed for in the BISRA specification or in B.S. 2573, so that some economy in design could be achieved there.

Mr Buchanan referred to recent work on fatigue factors based on 2 million stress cycles. In any such investigation note should be taken that the crane may have infrequent heavy loading and very frequent light loading, and that the light loading can also give rise to fatigue failure under certain conditions.

If higher stresses are to be permitted, the specifications on the testing of cranes and the motions and rate of deceleration permissible with the test load should also be clarified.

Mr **Buchanan:** We are very grateful to Mr Wilson for contributing to the discussion. First, in connection with the deceleration values, the crane to which he referred was a rather large one, of which only one of the four wheels was driven. That would affect the deceleration which could be applied. We would normally recommend a value of 0·1 g for cranes of which half the wheels were driven and 0·05 g where only one in four was driven. That does not differ greatly from Mr Wilson's figure of 1·7 ft/s², which he said was under extreme conditions of operation. For a company interested in raising the safe working load on the cranes it remains a question whether it is to take really extreme values of conditions of work, or more normal work in the shop. That is beyond the bounds of any specification.

Mr Wilson's second point dealt with the distribution of stresses across the top flange, and the fact that they are not uniform under lateral loading. B.S. 449 makes some allowance for the use of higher permissible stress, when that occurs. I have discussed this point with Mr Wilson and I still think that where repeated loadings occur and where there is a possibility of fatigue effects we must consider that trouble might arise on the extreme fibres. That is what is important, and not the question whether or not the stress is uniformly distributed. Therefore I do not think that any further allowance should be made in our case, as in B.S. 449, which deals only with buildings and fairly constant loading.

Mr Wilson referred to the work of the committee on B.S. 153 in amending its fatigue factors. I am not directly in contact with the committee, and I can only hope that those responsible for drawing up the B.S. specifications will see that all committees who have any interest in the matter will be kept informed.

The next point raised referred to the test loads to be applied. There again there has been some recent discussion in the B.S.I., where B.S. 2573 is being reconsidered, and there has been some improvement in the wording dealing with how much load should be on the crane during test and how that load is to be handled.

As for the 2 million cycles, we are at the moment erring on the safe side owing to lack of knowledge. We are hoping to perfect the use of an instrument for recording stress cycles both in magnitude and frequency, and that will yield some information on the question of the frequency of high or full loading of the crane, as compared with the frequency of light loading, where perhaps only a partial load is being moved. Even then it will remain to assess the effect of that distribution of stressing or stress cycles on the strength of the material. This brings up the difficult question of fatigue damage the solution of which lies in the future.

Mr **W. R. Robertson** (Wellman Smith Owen Engineering Corporation, Ltd.): The most important section of the paper appears to me to be the last, dealing with 'Permissible Stresses.' B.S. 466, E.O.T. Cranes for general use, has now been completely revised and the BISRA Specification for Steelworks E.O.T. Cranes 1955 very nearly so.

For particulars of structural design, these specifications will be referred to a new common specification shortly to be issued entitled "Maximum Permissible Stresses in Cranes," which in turn represents a complete revision of report No. 2573 issued originally in 1955. This specification puts E.O.T. cranes in 4 classes covering light, medium, heavy, and extra heavy duty and the stress factors to be used in each case are 1·0, 0·95, 0·90, and 0·85 respectively. Although these figures are a considerable improvement on the 2573 report, perhaps Dr Terrington can explain how they were allocated.

Having multiplied the basic stress figures, 9·0 tons/in² in tension and 9·5 tons/in² in compression, by the stress factor, the result is then divided by an impact factor, a different value being given to each class of crane.

These impact factors follow very closely those incorporated in the 1955 BISRA specification but there is no suggestion anywhere that they bear any relationship to the hoisting speed. Professor Cranz, of Germany, recently published a paper on impact factors and his formula has the merit of taking hoisting speed into account. In justice to Mr Buchanan it should be mentioned that he also has published a paper on "Calculation of impact factors for E.O.T. cranes," and he follows the same lines as far as hoist speed is concerned.

There appears therefore, a definite omission in British Specifications and we feel this point should be further considered before final publication.

Taking the case of a ladle crane Class 4, having a stress factor of 0·85 and an impact factor of 1·2, the working stresses become 6·35 and 6·75 tons/in², tension and compression respectively. It is agreed that the user of a heavy-duty crane should be safeguarded, but working to these stress figures is putting the cranemakers in the position of producing girders which are too heavy, and eyebrows are raised when the necessary information concerning wheel loads is passed to the designers of the shop girders and columns.

There is another approach to the question of girder weight. It does not appear that any reduction in size of resistances, and contactor panels in particular, is to be immediately looked for. The housing of these units in the girder structure coupled with statutory clearances, insisted on by electrical engineers, gives girders, except in the case of long span cranes, having a ratio of depth/span which is quite outside good design.

My company approaches the problem from the point of view that a separate girder should be provided to carry panels and resistances, and with them the L.T. gear, leaving the main girders to be solely load carrying members. This means that the lighter girders supporting the electrical equipment can be made to their own depth and that the main girders can be more reasonably designed.

If strain gauge tests are to have any value at all, it cannot be overlooked that a close study of the tables given in the paper reveals that measured stresses are less than those used for calculation purposes.

BISRA tests on one of our 250-ton ladle cranes some years ago recorded stresses of about 80% of those calculated and also proved that the measured impact figure was 10% against 20% allowed for.

It is suggested therefore that there is room for revision and that the basic stress figures be increased to 10 tons/in² and the stress and impact factors modified so that a working stress of 7·5–8 tons/in² is obtained, taking all operating factors into account. The US AISE specification works to these figures.

This proposed increase in stress is justified and in our experience steelworks engineers will admit that they have made frequent requests in recent years for cranes to be upgraded in capacity. The percentage increase varies from 10% to as high as 30%. In making such a request to the cranemaker for his approval, and apart from the adjustments necessary to mechanical and electrical details, it can be said that the specification to which the crane was designed is being deliberately flouted. On the other hand, these cranes are still working satisfactorily with increased loads and it is safe to say that the measured structural stresses would not exceed those increased figures we are now proposing.

At the top of p. 376, reference is made to "Abnormal Usage." The 1955 BISRA specification deals with this point on p. 3 with reference to strippers and chargers. Applying the formula the result gives a quite ridiculous loading on the girders in the form of a twisting moment.

Taking a stripper of 90·0-ft span, dead weight of say 130 tons, the load to be applied to the mast at floor level would work out at 13 tons. The more realistic approach is to tell the cranemaker that the machine is to be designed for moving an ingot bogie train of say 300 tons dead weight and allowing traction of 25 lb/ton if the bogie bearings are sleeve type, the mast load becomes 3·3 tons, a much more sensible figure.

It has been common practice to introduce camber into crane girders but from a manufacturing viewpoint this does not make the cost of production any less. We see no reason why camber should not be omitted altogether, bearing in mind that the gantry girders on which the crane runs more often than not have no camber. Admittedly some care will have to be taken with the lining up of the L.T. cross shaft bearings but this is a simple matter and it is to be hoped that nobody is going to suggest that any additional loading worth talking about will be thrown on the trolley cross-traverse motor.

Mr **Buchanan**: I am faced with a list of rather difficult questions to answer. Mr Robertson speaks with great experience as a crane designer, and he has given a great deal of thought to the matter. Referring to stress factors for the appropriate classes he quoted figures of 1·0, 0·95, 0·90, and 0·85, and asked how they were allocated. Our answer is that we did not want to put any stress factor in: it was the cranemakers who insisted on them.

On hoisting speeds, it will be seen in the paper that the formula referred to by Lightfoot includes a velocity term, and the difficulty arises out of the large number of factors involved. There are three or four terms in the formula, and in a recent book the late Mr Broughton turns down the idea of including any formula on the ground of complication. It is up to the cranemakers' representatives to make clear how much complication in design methods they will accept.

On ladle cranes, Mr Robertson referred to an impact factor of about 20%, whereas it could be very much less. This point was specifically raised by us in a meeting of the *ad hoc* panel dealing with the steelworks specification. We asked for the factor to be reduced to 10%, but could not get our views accepted.

As for abnormal usage, we gave some figures in the tables which indicate that in our tests we were able to find stresses recorded that corresponded with this question of crab tipping. It is an extreme condition, and Mr Robertson may be right in insisting that steelworks should make sure that their workers only operate with bogies to a certain weight limit; but steelworks authorities may find it difficult to keep to that sort of regulation.

Dr **J. S. Terrington** (BISRA): The circumstances regarding the provision of the stress factors requested by Mr Robertson are exactly as stated by Mr Buchanan, i.e. the actual values were proposed by the crane makers themselves. We do not support the idea of inserting this additional factor for the various classes of crane and we would prefer to rely on the stress fluctuation factors, which theory shows to be adequate.

Concerning the tests themselves, these are unique in crane history because they have been carried out under operational conditions in iron and steelworks. Comprehensive tests on a complete range of crane types, such as those made by Mr Buchanan and Mr Tyler had so far not been made and I believe that the cranemakers agree that it constitutes a monumental piece of work.

Structural tests made by other organizations on bridges and buildings have very largely been of a static

nature, but in these tests, the authors have been able to record the transient dynamic effects on a mirror galvanometer continuously recording on photo-sensitized paper. So far an instrument having 12 channels has been used and now we are about to acquire a recorder with 25 channels.

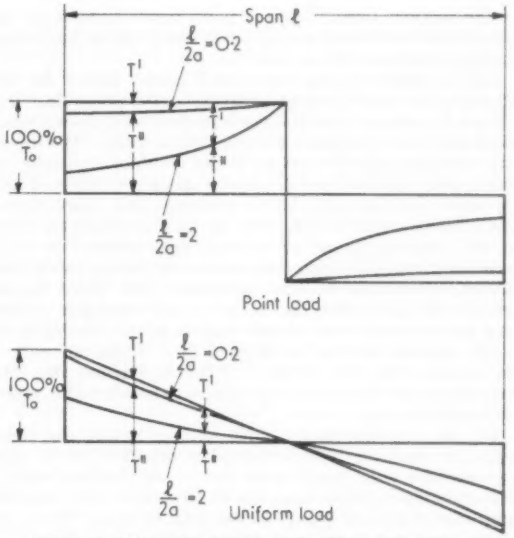
The authors have shown that the various groups of cranes require varying impact factors of e.g. 25, 50, and 100%, or even more, but there remains the controversial issue regarding the correct size of the test load. Thus, if the impact factor for a certain type of crane needs to be 50%, or even 100%, should the test load amount only to 25%? Opinion is still divided as to the most suitable value. Mr Wilson has referred to long travelling at speed with a load of 25% in excess of the safe working load. Now if in the case of a forging crane the impact factor is 100%, should the acceptance test be carried out with a test load of 100% in excess of the safe working load? It would appear to be doubtful practice to adopt such a high test load and, with it, to perform any vigorous movements.

Regarding abnormal loads, I strongly recommend that they should be calculated. The difficulties of doing this have been illustrated in the paper and I believe that the makers are rather reluctant to attempt it. Nevertheless, it would be better for some assessment of the abnormal loads to be made and the design prepared accordingly.

On the subject of permissible stresses, the tests have formed the basis of our conviction that stress fluctuation factors should be adopted in design. We included them in the BISRA specification and now they have been incorporated in B.S. 2573 covering all cranes. We are glad to see that the principle has been further elaborated by grading the number of stress cycles e.g. 100 000, 600 000, and 2 000 000, depending on the duty to which the cranes are subjected.

The values of the stress fluctuation factors have been obtained from US sources and were derived from tests on isolated specimens. I therefore suggest that some effort be made to check these values when applied to fabricated assemblies. We feel that this is an important issue and we would be glad to have the support of an interested body such as the Cranemakers' Association, to enable us to pursue research on it.

Mr Tyler is to be congratulated on having produced a simple method of analysing compound lattice girder types when twist is involved. I should, however, like to add a note to the ideas put forward in the paper. First, regarding bending about each transverse axis, this is reasonably straightforward but, in an asymmetrical section, account should be taken of the angle of inclination of the principal axes. Second, regarding the way in which compound girders resist any tendency to twist, there are two principal ways in which resistance to twist is afforded; one is by pure torsion as, for example, in a driving shaft, and the other is by increase or decrease in the bending of the component girders comprising the compound girder. The extent to which each of these two effects are present at any particular section along a beam or girder depends on the proportions of the member, namely the torsional strength compared with the bending strength of the component girders of the complete section in relation to the length of the girder and this has been referred to in another BISRA paper as a factor, $l/2a$ (where l is the span and a is a measure of the ratio of the torsional and individual bending strengths of the component girders of the section). With this factor as a kind of spectrum, scale, or 'yardstick,' any type of girder can be assessed. At one end of the scale are the welded box girders (where $l/2a$ is more than about 3), these are subject almost exclusively to pure torsion; intermediately are the rolled-steel sections (where $l/2a$ is between about 1·0 and 3·0), these are under both pure torsion and bending; and at the other end of the scale the open lattice, space-frame types (where $l/2a$ is less than about 1·0) these are subject wholly to bending and shear in the planes of their component girders. The last type has been dealt with specifically in Mr Tyler's paper.



$l/2a = 0·2$, 50-ft span box-type girder (lattice or part plate)
$l/2a = 2·0$, 14-in. broad flange beam on span of 14½ ft
When $l/2a$ is low (e.g. 0·2) total torque is resisted largely by bending of the 'flanges' or component beams

Fig. *A*—Proportion of total torque (T_o) resisted by (*a*) pure torsion (T'), (*b*) bending of 'flanges' or component beams (T'')

(Dr Terrington then illustrated his observations with a number of slides showing various types of section, their characteristics, and some calculations based on the general equations for bending and torsion and one of these is reproduced here (Fig. *A*). This shows for two conditions of loading on a beam or girder, namely a point load and a uniform load, that the proportion of the torque resisted by the two effects, namely pure torsion and bending of the component girders varies along the beam or girder and that this variation depends on the value of the factor $l/2a$. In the case of the open-type lattice girder, where $l/2a$ is low (0·2), the bending effect predominates; in the case of the rolled-steel joist, where $l/2a$ is moderately high (e.g. 2·0) the bending effect, in the case of the point load, predominates at mid-span, but at the end of the span and in the case of a uniform load everywhere in the span, the purely torsional effect is the more important.)

Mr **Tyler**: I thank Dr Terrington for his remarks in endorsing my methods of calculation of stresses. We tried to tie in the stresses we measured with the calculated ones and usually we were within about 10%. One point which came out was that the centre of the girder, which we normally strain-gauged, usually showed a fair agreement between the measured and the calculated stresses. We occasionally put strain gauges on the end panels, and there the results were never quite in agreement; in fact there were up to 50% variations in some cases between the measured and the calculated stresses, but this was mainly due to the diffusion of load up the slope of the girder to the end carriages, and the consequent rigidity of the tying together of the ends of sections, where stresses were small owing to the substantial nature

of the sections used. Further work needs to be done on the stresses in the end panels particularly those due to the racking loads on the girders.

Mr **J. Baker** (Clyde Crane and Booth Ltd): As Mr Tyler said, it was common practice, in the crane drawing offices, to assume that the main girders took the vertical loads and the outriggers the horizontal loads. We knew that outrigger girders gave a lot of trouble, especially in heavy-duty cranes, and gradually these got stiffened up, by additional bracing, extra riveting, and diaphragms but it was not until 1943, when we had a tension fracture in the bottom flange of an outrigger girder that we realized that something was seriously wrong with the design. We came to the conclusion that there was a transfer of load from the main to the outrigger girder and we devised a very simple means of calculating how much transfer should be allowed for. Then our calculations got into the hands of BISRA, I think that Mr Fealdman got them, and the ultimate result is the paper under discussion.

On the smaller cranes, with shorter spans, the time taken in making these elaborate calculations is not worthwhile; you spend more money in drawing offices than you save on the material in the shops. But on the long-span cranes economy in material is vital. We must know what our loading is and stress up accordingly.

In this respect the tests to date are a little disappointing. We are concerned with total stress, and are measuring only the live load stress. Further efforts should be made to get the total stress. I feel that BISRA should be able to invent some method of measuring total stress.

I do not like to suggest that any of BISRA's work is incorrect, but when measuring stresses with strain gauges in the neighbourhood of $\pm \frac{1}{2}$ ton/in^2 when the total stress in a member is about 6 tons/in^2 a very small error in a strain gauge can lead to a wrong conclusion.

On the question of snatch loading, we found a very marked difference between a new rope and a rope which had bedded down. If snatch loading depends on hoisting speed the snatch could be very easily damped out by spring suspension of the return end of the hoist rope.

If we are going to design cranes stressed up to the most economical limit of the material we must have much more effective buffer stops than at the moment. The ordinary railway-type buffer is virtually useless, and the standard hydro-pneumatic type very little better. We must have a buffer capable of decelerating the wave at a safe rate having available about 5 ft of track at the end of the shop in order to give room for the stroke of the buffers.

B.S. 2573 and the factor D.2 was mentioned in connection with horizontal loading. At the last B.S.I. meeting the D.2 factor was eliminated, which will be pleasant news to BISRA.

We are inclined to forget that structures possess an inherent damping capacity; some structures are good at absorbing shock and some are not. Professor J. P. den Hartog* recently gave a paper on vibration, although the paper deals mainly with blades, it also describes the natural capacity that some machines have for damping. If BISRA could investigate this damping effect it would be a great help to crane designers. Sometimes a structure with loose rivets stands up to hard work much better than one which is welded up tight.

This morning's discussion has been concerned with the loading of girders, but no one has mentioned the connection to the end carriages. The calculations are not applicable when one considers the tendency of a crane to 'rhombus.' The shown load from the end carriages has to be transmitted to the girders through the bottom flanges of the main and auxiliary girders.

I was surprised to find that there was some apprehension on the part of crane drivers to reversing the travelling controllers. My experience is that all crane drivers go from full forward to full reverse without hesitation, so much so that the heavier cranes are designed to withstand this treatment. I am sure that Mr Robertson's remarks are directed to cranes fitted with current-limiting devices, because on any crane fitted with this device you can reverse the controller with safety. Cranemakers know what the deceleration should be and the crane is designed to stand it.

The uncertainty of how a test load should be handled has surprised me. It has always been the view of B.S.I. that the test load is equivalent to a static test, and I did not realise that it was not clear in B.S.I. specifications. B.S.I. are revising some crane specifications and it must be made clear that that is the case.

As to the value of 'overload' tests, I think it was Brierley who said that "the tensile testing is a useful thing from a sales point of view, but conveys no additional knowledge to a discriminating steel manufacturer"; the same remarks apply to overload testing of cranes.

Mr **S. Burrows** (Adamson-Alliance Company Ltd): The tone of some of the discussion suggests that the cranemaker is a 'retarding factor' on the 'long travel' of crane progress and is slow to make use of the findings of research. The reply would seem to be that the cranemaker of long standing wishes to ensure long travelling time for his crane.

Whilst an analysis of stress conditions is a most useful guide, it is incomplete without an analysis and a verdict based on a long term of service. The cranemaker plans for this long crane life and probably this accounts for a somewhat conservative attitude towards design.

Mr **R. W. Davis** (John Summers and Sons Ltd): My experience as a maintenance engineer leads me to join Mr Baker in his observations about end connections. Our principal concern in the structure of the cranes we have to deal with has not been with the girders and we have had little trouble with the girder structures. Loose rivets are very rare, and girder failure is unknown in my experience. We have, however, certain relatively fast cranes with which we have had considerable trouble at the end connections, presumably shear failures, but although they have not reached the stage where they have become dangerous, they have caused frequent stoppages.

I disagree with Mr Buchanan's comment that the indeterminate impact derived from the crane rails was largely due to poor maintenance, and had nothing to do with the original design. There are certain gantries in which it is virtually impossible, no matter how thorough the maintenance, to do anything at all, short of dismantling and rebuilding.

I should be grateful if the nature of the abnormality in crane usage could be assessed and given some form of quantitative treatment, but I think it is unlikely, because from my observations I believe that the ingenuity of the drivers and the operators of certain process cranes is superior to that of the designers. Under these circumstances, only mechanical, electrical, or structural failure will limit the demands made on the crane.

Mr **B. R. Jackson** (Stewarts and Lloyds Ltd): Are the authors able to indicate an optimum yield/ultimate ratio for the steel used in crane structures? If so, have they any recommendations for the steel quality?

Have they considered the application of a weldable high-strength steel, such as Fortiweld, to reduce dead weight of the crane? Can significant results be obtained from the testing of models as an aid to crane design?

* J. P. DEN HARTOG: Spec. Publ. Institution of Mechanical Engineers, 1957.

Does Mr Tyler prefer that flexure or torsional movements occur chiefly in the members, or in the corners of the structure, and has he any comments on the use of bolted joints as compared with riveted joints ?

Mr **Buchanan**: On the point about steel quality, primarily with reference to welding, I think we state, in the BISRA specification, appropriate factors and stresses dealing with some of the high-tensile steels. One of the difficulties which is always brought up is that of the requirement of deflection as well as stress, because the value of Young's modulus is the same for high tensile as for mild steel. One has to design a crane for the requirements of stresses and deflection. That imposes some limitation on the steel.

On the subject of testing models, Dr Terrington did an extensive investigation on crane gantry girders, and he would say that that was quite successful. It is successful inasmuch as one can discover the reaction of certain types of structure to a known load. It still leaves open the question of what loads the structure will receive in practice, and that is where site testing comes in.

Mr Davis referred to the ingenuity of crane drivers, and we agree with him about that. He also referred to crab tipping, but even crane drivers do not like to see their mast or crab tipping up, and a certain amount of native caution would enter into the matter there.

Mr Burrows referred to the solution lying in collaboration between ourselves and the Cranemakers' Association, and we heartily agree. We have learned a lot from them in the time we have been engaged on these tests, and could not possibly have produced our report without a very high degree of co-operation from them in furnishing details of the cranes tested and many other ways.

Mr **Tyler**: On the question of optimum yield to ultimate, the ratio of yield to ultimate stress for hot-rolled mild steel is of the order of 15 : 25. The aircraft industry does not use it, preferring the bright-drawn variety which has a much higher ratio of the order of 24 : 30 so that there is a failure soon after the yield stress of 24 tons has been exceeded. While advantage can be taken of the higher yield in design, the reserve of plastic strength is very much less, so that there would be less distortion of a structure before failure. This is satisfactory for aircraft where the life is only two or three years, but whether or not the material would be satisfactory for cranes where severe overload at present leads to distortion rather than failure is another matter. A weldable 40-ton tube could certainly be used for a crane structure if the welds were satisfactory, but perhaps there should be a good percentage elongation to failure in the material.

On the use of models: a model is not the same as the real thing. It is better to reduce the size from 70 ft to 20 ft than from 70 ft to 5 or 6 ft, because it is so small that it cannot reproduce the connections, and the whole thing gets completely out of proportion.

I do not appreciate the point about torsion of the box section. With the diagonal across, the rectangular shape is also maintained, at least from panel point to panel point, and since it will behave, theoretically, as a perfect space frame it would not appear to have torsional troubles either side of the joint.

With regard to bolted joints as compared to riveted joints, if you bolt a joint you pre-stress it to some extent, and if you make sure it remains tight it should be perfectly satisfactory.

Dr **Terrington**: Could Mr Baker give some information about high-strength bolts ?

Mr **Baker**: I am not unbiased on this question of the use of high-strength bolts. I think that eventually all 'field' rivets will be replaced by high-strength bolts. Some cranemakers would not agree with that statement. When you design a structure for riveting and fitted bolts you have two sizes of hole to deal with in the shops, and you invariably manage to get bolt holes where there should be rivet holes, and *vice versa*.

With the high-strength bolt all the holes are the same size, so that if the shop wants to make a change in the size in which components are despatched you have only to rearrange the rivets.

We have used about 17 000 high-strength bolts on a crane at Bradwell, which cut erection time by 3 months. Tightening was done by compressed-air impact wrenches and checking by a hand-operated torsion spanner. It did not seem necessary on a large joint to go back over the bolts; the initial tightening of each bolt was sufficient. It is essential to have high-tensile steel washers under each bolt head and nut, otherwise the pull of the bolt distorts the material. Up to date there is no tendency of the bolts to work loose, and I do not believe there will be any such tendency.

There is a new type of high-tensile bolt, with a square end protruding beyond the nut, a V-notch is cut between the end of the threads and the beginning of the square; the wrench exerts its torque by virtue of the reaction between the nut and the square, you go on tightening until the square end shears off. The diameter of the notch fixes the amount of torsion. The only snag is that the position of the notch is important, and it is difficult to forecast, with multiple bolting, just how thick the grip of the bolt will be.

Mr **W. R. Robertson**: Initial experience with high-tensile bolts probably requires two operations, to tighten the bolt and then check it with a torque spanner. A measure of the torque put on a bolt can be the time taken in tightening up with the air wrench.

The 'shear' bolt is a simple and yet ingenious unit provided with a correctly machined portion at bottom thread level on the screwed shank just proud of the nut. The bolt extension shears at the pre-determined stress and no check is necessary. The air wrench required, however, can be a costly piece of erection equipment.

Dr **Terrington**: Are high-strength bolts likely to supersede welding itself ?

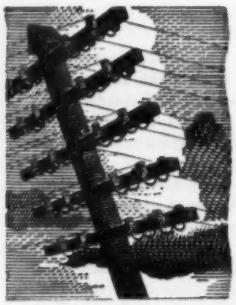
Mr **Baker**: We must build some degree of flexibility in welded structures. The shipbuilders are welding large sections of ships and riveting the sections together. High-tensile bolts used for site points might provide the damping capacity required.

Mr **Tyler**: If you make a Vierendeel truss the whole section is bending, and because of that flexibility you might not need the safeguard of welding the corners so much.

Mr **T. B. Rolls** (McLellan and Partners): Earlier in the discussion electrical engineers were criticized for the clearances they demand. When the voltage exceeds 250 V they are, however, only obeying the law, namely regulation 17 of the Electricity (Factories) Act Special Regulations 1908 and 1944.

It is possible to avoid the requirements of this regulation if the voltage is under 250 V. This is practical only in reasonably compact works, such as would be met in the production of tinplate, whereas an integrated iron- and steelworks, which is larger both geographically and in the load requirements, would need a higher voltage. Even where the lower voltage can be used reasonable clearances are needed to enable the electricians to watch the contactors operate in safety and the clearances would need to be almost as great as the statutory requirements of regulation 17.

It must be admitted that some crane contactor panels seem large and heavy but it is doubtful whether smaller and more compact equipment would be suitable for the onerous conditions in a steelworks.



N E W S

Announcements and News of Science and Industry

THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1959

The Annual General Meeting of the Institute will be held in London on **6th and 7th May.** The programme is as follows:

WEDNESDAY, 6th MAY (at the Hoare Memorial Hall, Church House, Great Smith Street, London S.W.1)

10.0–11.0 a.m. Formal business, including presentation of Report of Council and Accounts for 1958; presentation of medals and awards; election of members.

11.0—11.45 a.m. Induction of the new President, Mr W. Barr, O.B.E. Presidential Address

12 noon–1.0 p.m. and 2.30–5.0 p.m. } Technical sessions

Technical Session A—"**Recent Applications of Oxygen to Steelmaking**" (in the Hoare Memorial Hall, Church House)

12 noon–1.0 p.m. Introductory review of present-day steelmaking processes, by Dr T. P. Colclough, C.B.E.

2.30–5.30 p.m. Presentation and discussion of the following papers (dates of publication in the *Journal* in parentheses):

- "Some investigations on the treatment of molten iron," *by W. J. B. Chater and J. A. Charles* (April 1959)
- "The practical aspects of pretreatment processes," *by J. L. Harrison* (April 1959)
- "The L-D Process," *by O. Cuscoleca* (to be preprinted)
- "Comments on the O.L.P. process," *by B. Trentini, P. Vayssière, and M. Allard* (to be preprinted)
- "Further experience on the Kaldo process," *by B. Kalling and F. Johansson*

Technical Session B—"**The Formation of Bainite**" (in the Convocation Hall, Church House)

2.30–5.30 p.m. Presentation and discussion of the following papers:

- "The kinetics of bainite formation in a plain carbon steel," *by P. Vasudevan, L. W. Graham, and H. J. Axon* (December 1958)
- "The kinetics of the formation of bainite in high-purity iron–carbon alloys," *by S. F. Radcliffe and E. C. Rollason* (January 1959)
- "The effect of austenitizing treatment on the formation of lower bainite in a plain carbon steel," *by L. W. Graham and H. J. Axon* (April 1959)

7.0 for 7.30 p.m. **Dinner for Members** at Grosvenor House, Park Lane, London W.1.

THURSDAY, 7th MAY (at the Hoare Memorial Hall, Church House)

Technical Session A (contd.)—"**Recent Applications of Oxygen to Steelmaking**" (at the Hoare Memorial Hall, Church House)

10.0 a.m.–1.0 p.m. Presentation and discussion of the following papers:

- "Recent developments in oxygen steelmaking in North America," *by J. M. Gaines* (to be preprinted)
- "The use of oxygen in a modified tilting furnace," *by A. Jackson* (September 1958)
- "The use of oxygen in a modified tilting furnace: a progress report," *by A. Jackson* (April 1959)
- "The use of oxygen in duplex and stationary open-hearth practice," *by O. Pearson* (April 1959)
- "The refining of molten pig iron in electric-arc furnaces," *by R. Durrer and R. Heintze* (to be preprinted)

Technical Session C—"**Hydrogen in Steel**" (in the Convocation Hall, Church House)

10.0 a.m.–1.0 p.m. Presentation and discussion of the following papers:

- "The diffusion of hydrogen in steel at temperatures of −78° to 200° C," *by J. D. Hobson* (August 1958)
- "Hydrogen in ferrosilicon," *by N. Christensen and K. Gjermundsen* (November 1958)
- "The determination of hydrogen in steel by a carrier-gas technique," *by C. E. A. Shanahan and F. Cooke* (December 1958)
- "The removal of hydrogen by diffusion from large masses of steel," *by J. D. Hobson* (April 1959)

END OF MEETING

NEWS OF MEMBERS

Dr **D. V. Atterton** has been appointed managing director of Foundry Services Ltd.

Mr **E. W. Colbeck** is deputy chairman of Hadfields Steels Ltd. and *not* Hadfields Ltd., as reported in the March issue.

Mr **J. F. G. Condé** has joined the U.K. Atomic Energy Authority, Industrial Group, at Risley, as a principal scientific officer.

Dr **Karl L. Fetters** has been elected vice-president, research and development, of the Youngstown Sheet and Tube Company.

Dr **F. W. Jones** has succeeded Mr J. Woolman as manager of the Brown-Firth Research Laboratories; he has been appointed a local director of Thos. Firth and John Brown Ltd.

Mr **J. M. Keefe** has been appointed deputy hot mills manager at the Steel Company of Wales Ltd.

Mr **H. W. Kirkby** has been appointed to the board of Thos. Firth and John Brown Ltd.

Mr **W. Lumb** has left Shepcote Lane Rolling Mills Ltd. to become metallurgist to Firth-Vickers Stainless Steels Ltd.

Mr **S. P. Maynard** has been appointed technical adviser on the steel industry to Brookhirst Igranic Ltd.

Dr **W. I. Pumphrey** has been elected a representative of the Guild of Graduates on the Court of Governors of Birmingham University.

Dr **F. N. Rhines** has been appointed Professor of Metallurgical Engineering at the University of Florida, College of Engineering, Gainesville, Fla.

Mr **M. A. Scheil** has been elected a trustee of the American Society for Metals for 1959–1960.

Mr **J. Woolman** has retired from his position as manager of the Brown-Firth Research Laboratories and as a local director of Thos. Firth and John Brown Ltd., after 39 years' service.

Obituary

Dr **Marce Ballay** (*elected* 1935), of Paris, on 2nd February, 1959.

Mr **Cyril Francis Hill**, M.I.M.M., A.INST.P. (*elected* 1912), of Warrington, on 28th July 1958.

Mr **Harry Powell** (*elected* 1936), of Rotherham.

Mr **John Allon Thornton**, M.INST.C.E., M.I.MECH.E. (*elected* 1931), of Huddersfield, on 31st January, 1959.

Mr **John Spilman Walton**, F.I.M. (*elected* 1925), of Briton Ferry, in December, 1958.

IRON AND STEEL ENGINEERS GROUP

Meeting in the Netherlands

At the invitation of Mr A. H. Ingen-Housz (*Past President*), who was until his recent retirement President of the Royal Netherlands Blast Furnaces and Steelworks Ltd., the Iron and Steel Engineers Group is holding a meeting in the Netherlands from Tuesday, **14th April,** to Friday, **17th April.** The programme is as follows:

Tuesday, 14th April

2.30–5 p.m. Technical session at the Grand Hotel Krasnapolsky, Amster-

dam. Mr F. B. George, Chairman of the Group, will be in chair.

Lecture on the world iron-ore situation, by Mr. C. R. Wheeler, C.B.E., President of The Iron and Steel Institute.

Presentation of the following papers:

"*The Muller-Hanna ore-handling installation at the Port of Rotterdam*," by F. D. Vines

"*Ore-transfer facilities at Contrecoeur, Quebec*," by D. H. Sharp

"*Ore-handling facilities at Seven Islands, Quebec*," by D. H. Sharp

"*Transportation and handling of ores in Great Britain*," by T. V. Nicholson.

"*The unloading of iron-ore ships in the USA and Canada*," by H. R. Mills

Wednesday, 15th April

9.30–12 noon Technical session at the Grand Hotel Krasnapolsky. Discussion of the papers presented on the previous afternoon.

2.30–5 p.m. Technical session at the Grand Hotel Krasnapolsky. Presentation and discussion of the following papers:

"*Ore crushing*," by A. Kjelgaard.

"*Screening blast-furnace burden materials*," by H. N. Wilkinson and E. E. Farmer.

"*Problems of ore handling—Part I: Ore handling at Port Talbot*," by J. E. Robson.

"*Problems of ore handling—Part II: Ore handling at East Moors Works, Cardiff*," by T. Jenkins.

"*Raw materials handling problems in steelworks. Part I—General handling problems*," by H. Swindells

"*Part II—Ore preparation and blending*," by R. Bartram.

Thursday, 16th April

9 a.m.–10 p.m. All-day visit to the Royal Netherland Blast Furnaces and Steelworks Ltd., IJmuiden.

Friday, 17th April

8.56 a.m.–11.30 p.m. All-day visit to Rotterdam. Visits will be paid to the Rotterdam Dry Dock Co., Ltd., and the Muller-Hanna ore-handling installation.

Preprints of all the papers to be presented, with the exception of Mr Wheeler's lecture, will be available in advance of the meeting. A bound volume of proceedings of the meeting will be published later in the year in the Institute's Special Report Series.

The maximum number of members who will be able to attend the visits to IJmuiden and Rotterdam will be 150; it will, however, be possible to accommodate up to 250 at the technical sessions in Amsterdam. Notices of the meeting and reply forms have already been circulated to members.

THE INSTITUTE OF METALS

New publication

The proceedings of a symposium on "*Vacancies and other point defects in metals and alloys*," organized recently by the Institute's Metal Physics Committee, have now been published. The book consists of six papers on this important and rapidly expanding field of metal physics, together with a full report of the discussion, in which a great deal of new work was reported. Copies may be obtained through booksellers or direct from the Institute, price 40*s*. (post free). Members of The Institute of Metals are entitled to purchase one copy at a special rate of 28*s*. (post free).

BRITISH NUCLEAR ENERGY CONFERENCE

Meetings in April

The following meetings have been announced:

10th April "*Some highlights of high-power heavy-water moderated nuclear reactors*," by Dr. W. B. Lewis (James Clayton Lecture): Institution of Mechanical Engineers, 1 Birdcage Walk, London S.W.1, 6 p.m.

14th April "*Metallurgical developments outlined at the Geneva Conference on the peaceful uses of atomic energy*," by Dr. H. M. Finniston: Church House, Great Smith Street, London S.W.1, 10 a.m.

29th–30th April Convention on "Thermonuclear Processes": Institution of Electrical Engineers, Savoy Place, London W.C.2, 10 a.m.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Civil and Structural Engineering Conference

A conference entitled 'Iron and Steelworks Buildings,' organized by the Plant Engineering and Energy Division of the British Iron and Steel Research Association, was held at Ashorne Hill, Leamington Spa, on 14th and 15th January, 1959, under the chairmanship of Mr R. L. Willott, D.S.O., O.B.E. (John Summers and Sons Ltd.) and more than 140 representatives attended. Ten papers were presented, dealing with design and construction of foundations and superstructures of iron and steelworks buildings in the United Kingdom, on French, German, and U.S. practice, on research and development in this field being carried out by BISRA, and on the architectural aspects of iron and steelworks buildings.

The first paper, '*Foundations to iron and steel works buildings*' by Mr W. S. Atkins (presented by Mr K. N. Drobig of W. S. Atkins and Partners) pointed out the desirability of a thorough preliminary site investigation and the advantages that may be obtained in laying superstructure foundations before plant foundations. The paper contained an example of the planning and management of a contract and discussed the best form of contract in different situations.

This was followed by a paper entitled '*Some notes on the iron and steelworks buildings at Corby Works*' by Mr T. E. Clements (presented by Mr J. T. E. Williams of Stewarts and Lloyds Ltd.), which described the difficulties encountered on a site comprising natural ground, backfill, and the levelled remains of a slag heap, including the foundations of old blast-furnaces, and gave details of the foundations, including the six different types of pile used.

The following session comprised two papers. '*Some notes on modern steelworks structures*' by Mr E. F. Woolridge and Mr N. Lancaster (United Steel Companies Ltd.) dealt with the design and construction of building structures covering certain steelworks requirements and reviewed the form of construction in relation to the fundamental needs of an electric melting shop and a medium-width hot strip mill, and also dealt with the reconstruction, without interrupting production, of a billet mill, building on a completely surrounded site. This was followed by '*Load distribution through a melting-shop stage and gantry rail maintenance*' by Mr D. B. Wilson (The Steel Company of Wales Ltd.), which described investigations on the strength, under the action of an excavator for demolishing open-hearth furnaces, of a melting-shop stage using electrical resistance strain gauges, and the practice of gantry rail welding and lubrication to avoid crabbing of the cranes during long travel, with details of the standard rail clip used at the Steel Company of Wales.

The two papers in the next session were '*Superstructures to iron and steelworks buildings*' by Mr K. F. Geesin (Colville Construction Company Ltd.) and '*Iron and steelworks buildings*' by Mr E. Ibbotson (Dorman Long (Bridge and Engineering) Ltd.). The first presented the construction of the ironworks buildings at Ravenscraig as examples of current Scottish ironworks construction practice and discussed problems of planning, design, and construction of a modern steelworks. The second paper described trends in the design of steelworks buildings since the war, and detailed the factors affecting the decisions taken in the early stages of planning and those factors that have a large effect on the ultimate cost of construction.

The fourth session was devoted to papers on continental and US practice. The first paper, '*The framework of buildings used in the iron and steel industries in France*,' by M A. Delcamp, was presented by M H. Lepeu (Chambre Syndicale de la Construction Métallique) and gave details of the construction of open-hearth and rolling-mill buildings. '*Examples of iron and steelworks buildings in Germany*' by Dr G. F. Drath (Fried. Krupp Industriebau) compared the layout and construction of iron and steelworks building in Germany with those in other parts of Europe, India, the USA, and the Far East, including melting shops for the new oxygen steelmaking processes. The session concluded with '*Some notes on the steelworks buildings of the Fairless Works of the United States Steel Corporation*' by Mr C. H. Good, Jnr., presented by Mr P. D. Thompson (British Iron and Steel Research Association), which gave a brief outline of the general design aspects of the mill buildings at Fairless Works, including the reasons for the omission of natural illumination in all the operating buildings.

The paper '*Research and development in relation to buildings and structures in the iron and steel industry*' by Dr J. S. Terrington, Mr D. Buchanan, and Mr P. D. Thompson (British Iron and Steel Research Association) was presented by Dr Terrington. The paper gave a survey of general design considerations and current trends in design, and described recent, current, and possible future research by BISRA on structures.

The final paper presented at the Conference, '*Architectural aspects of iron and steelworks buildings*' by Mr F. Gibberd, C.B.E., F.R.I.B.A., considered the siting and site layout of iron and steelworks, and gave examples showing the importance of the choice of cladding material, design of detail, and use of colour in industrial buildings.

The full proceedings of the conference, together with the papers, will be published in due course.

Mr E. W. Voice

Mr E. W. Voice, B.SC., A.INST. G.E., A.INST.P., Head of the Ironmaking Division, has been appointed an Assistant Director of BISRA.

Mr Voice was educated at Latymer Upper School, London. In 1930 he joined the Gas, Light, and Coke Co. Ltd., in the company's research laboratories, working on the domestic utilization of coal gas. He obtained an honours degree in physics at the University of London in 1938.

From 1939 to 1946 Mr Voice was seconded to the Ministry of Supply, and worked on chemical warfare projects. In 1946 he joined BISRA, working at Normanby; for a short time he led a team at Appleby-Frodingham concerned with the provision of design data for *Sinterphim* sinter plant.

In May, 1952, he joined the Central Research Establishment of the National Coal Board as Assistant Director to Dr J. Bronowski, and was eventually appointed acting Director of the Board's Mining Research Establishment.

In June, 1954, he returned to BISRA as Head of the Ironmaking Division in succession to Dr Saunders. He combined this with the position of Head of BISRA's Chemistry Department in September, 1956.

CONTRIBUTORS TO THE JOURNAL

H. J. Axon, B. MET., D.PHIL.—Senior Lecturer, Department of Metallurgy, University of Manchester.

Dr Axon, who was born in 1924, studied first under Professor J. H. Andrew at Sheffield University, where he obtained his B.Met. degree and was awarded a Mappin Medal. He then went to Oxford, to work under Professor W. Hume-Rothery, F.R.S.; as a result of his work at Oxford, he was awarded the degree of D.Phil. After two years at the A.E.I. Laboratory, Aldermaston Court, Dr Axon went to Manchester University as I.C.I. Fellow, working with Professor F. C. Thompson. He was subsequently appointed to his present position, and is currently engaged on a study of metallic meteorites. He is a member of the Council of the University of Manchester.

A. S. D. Barrett, B.SC., M.I.MECH.E., A.M.I. CHEM.E.—Technical Director, Edwards High Vacuum Ltd.

Mr Barrett graduated from King's College, London, in 1929 with a B.Sc. (Honours) degree; he was also awarded the Jelf Medal. Until 1933 he was engaged in research on high-speed oil engines with Professor S. J. Davies, first at King's College and later as a consultant in industry. He joined I.C.I. Ltd. (Billingham Division) in 1933; he was granted leave of absence during his tenure of a Blair Fellowship in chemical engineering at the Massachusetts Institute of Technology from 1938 to 1939. Mr Barrett was recalled to a Supplementary Reserve unit on the outbreak of war, and served as a Captain in the Royal Engineers until 1941, when he was released from the Army at the request of I.C.I. to join Tube Alloys (the atomic energy project). He became interested in high-vacuum techniques during his period with Tube Alloys, and later joined his present company (then W. Edwards and Co., Ltd.) as technical director.

J. A. Charles, B.SC., A.R.S.M., A.I.M., A.M.I.M.M.—Senior Metallurgist, British Oxygen Research and Development Ltd.

Mr Charles was born in 1926 and educated at Bromley County Grammar School, Cambridge High School, and the Imperial College of Science and Technology, graduating with a 1st Class Honours degree and Associateship in Metallurgy from the Royal School of Mines in 1947. His first appointment was with J. Stone and Co. Ltd., Deptford, where he worked on the improvement of bearing alloys. He joined British Oxygen in November, 1950, and has been concerned since with research and development on the use of industrial gases in metallurgical processes, principally the use of oxygen in iron and steel production.

He is joint author with W. J. B. Chater and J. L. Harrison of the book "Oxygen in Iron and Steelmaking," published by Butterworths Scientific Publications Ltd. in 1956.

W. J. B. Chater, M.A. (CANTAB.)—Manager, Metallurgy and Equipment Department, British Oxygen Research and Development Ltd.

Mr. Chater, who was born in 1917, was educated at Northampton School and Christ's College, Cambridge. He was with the International Electrolytic Plant Co. Ltd. from 1940 to 1945 and Bamag Ltd. from 1945 to 1948. He joined British Oxygen in 1948, and is now manager of the Metallurgy and Equipment Department of BORAD, which deals with research on cutting, welding, equipment, and steelmaking.

L. W. Graham, B.SC. (HONS.) MET., PH.D.—Hawker Siddeley Nuclear Power Co. Ltd.

Leslie Wilfred Graham was born at Warrington in 1932 and educated at Bryanston School and Manchester University, where he obtained his bachelor's degree in 1953 and his doctorate in 1956. After one year as Assistant Lecturer in Metallurgy at Manchester, he joined his present company, where he is mainly concerned with the development of graphite, particularly for the high-temperature gas-cooled reactor.

M. E. Harper, GRAD.INST.P.—Section Leader, Vacuum Metallurgy Section, Edwards High Vacuum Ltd.

Mr Harper was born at Nuneaton in 1929 and educated at Handsworth Technical School, Birmingham. From 1944 he underwent laboratory training in inorganic analysis with Minworth Metals Ltd., Birmingham, until he joined the Royal Air Force in 1947. After two years' service he was demobilized and joined the research laboratories of A.E.I. Ltd. at Aldermaston, as a technical assistant in the physical metallurgy section, where he was engaged on research on alloy development, pure melting techniques, and the development of arc furnaces. During his period with A.E.I. Mr Harper studied part-time at Reading Technical College and Northampton Polytechnic, leading to a graduateship of the Institute of Physics. He took up his present post in 1954, and has since been concerned with research and development of vacuum-metallurgical processes, the development of arc furnaces, etc.

L. W. Graham

M. E. Harper

EDUCATION

Mond Nickel Fellowships

The Mond Nickel Fellowships Committee now invites applications for the award of Mond Nickel Fellowships for the year 1959. Awards will be made to selected applicants of British nationality educated to University degree or similar standard, though not necessarily qualified in metallurgy, who wish to undergo a programme of training in industrial establishments; they will normally take the form of travelling Fellowships; awards for training at Universities will only be made in exceptional circumstances. There are no age limits, though awards will seldom be given to persons over 35 years of age. Each Fellowship will occupy one full working year. The Committee hope to award up to five Fellowships each year of an approximate value of £900–£1 200 each.

Mond Nickel Fellowships will be awarded in furtherance of the following objects:

(*a*) To allow selected persons to pursue such training as will make them better capable of applying the results of research to the problems and processes of the British metallurgical and metal-using industries.

(*b*) To increase the number of persons, who, if they are subsequently employed in executive and administrative positions in the British metallurgical and metal-using industries, will be competent to appreciate the technological significance of research and its results.

(*c*) To assist persons with qualifications in metallurgy to obtain additional training helpful in enabling them ultimately to assume executive and administrative positions in British metallurgical and metal-using industries.

(*d*) To provide training facilities whereby persons qualified in sciences other than metallurgy may be attracted into the metallurgical field and may help to alleviate the shortage of qualified metallurgists available to industry.

Applicants will be required to state the programme of training in respect of which they are applying for an award, as well as particulars of their education, qualifications, and previous career. Full particulars and form of application can be obtained from The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London S.W.1.

Completed application forms will be required to reach the Secretary of the Committee not later than 1st June, 1959.

Lectureship at Liverpool

Applications are invited for the post of Lecturer in the Department of Metallurgy at Liverpool University to teach and carry out research in physical metallurgy. The initial salary will be within the range £900–1 250 per annum, according to age, qualifications, and experience. Applications, stating age, academic qualifications, and experience, together with the names of three referees, should be received not later than 18th April, 1959, by the Registrar, from whom further particulars of the conditions of appointment may be obtained.

A. S. D. Barrett

J. A. Charles

W. J. B. Chater

NEWS OF SCIENCE AND INDUSTRY

Iron and Steel Gallery at Science Museum

Lord Mills, Minister of Power, officially opened the new Iron and Steel Gallery, which commemorates the centenary of Bessemer's invention of the pneumatic steelmaking process, at a ceremony at the Science Museum, South Kensington, on 6th February.

The new gallery was created with the aid of the British Iron and Steel Federation, at a cost of £60 000. In a space of about 35 000 ft² a series of exhibits drawn from existing Science Museum collections and contributed by makers and users of steel tells the story of the development of the industry from prehistoric times to the present day, using the latest exhibition and display techniques. The subject is so vast that only the most important technological advances can be illustrated, but the overall picture is as comprehensive as the limited space will permit. The exhibits cover direct reduction of iron ore, charcoal pig iron and its fining to malleable iron, coke iron, modern blast-furnace practice, foundrywork, cementation and crucible steel, Bessemer, open-hearth, and alloy steelmaking, and modern methods of casting, forging, rolling, and drawing. As an introduction for the layman to the history and technology of iron and steelmaking, the new gallery could hardly be bettered.

Brick for hot tops

The subject of hot-topping of ingots has recently received a great deal of attention (e.g. Aitken, Fletcher, and Fenton, *JISI*, December, 1958). The need for a cheap expendable insulating brick has long been recognized, and so it is interesting to learn that Foundry Services International Ltd. and Thomas Marshall and Sons Ltd. have developed such a brick, known as "Fabrex." These are porous insulating bricks made from a bonded synthetic aggregate. Its refractory properties are roughly the same as those of ordinary siliceous refractory shapes, but with superior K values. Complete dimensional stability is achieved in manufacture, which makes accurate shaping both simple and reliable. Fuller details may be obtained from the companies responsible for developing the material.

The yard and the pound

The directors of standards laboratories in Australia, Canada, New Zealand, South Africa, the UK, and the USA have agreed to adopt an international yard and pound avoirdupois having the following definitions:

yard 0·914 4 metre
pound 0·453 592 37 kilogram.

All non-metric calibrations carried out in the laboratories mentioned for science and technology will be made in terms of these units on and after 1st July, 1959.

The Board of Trade points out that these units have no statutory force in the UK, and that for trade purposes the imperial units laid down in the Weights and Measures Act of 1878 remain in force.

Plastic-coated steels

An exhibition was recently held at the Royal Festival Hall, London, to display the wide range of uses of Stelvetite, the plastic-coated steel sheet marketed by John Summers and Sons Ltd. This material—26 to 16 gauge cold-reduced steel sheet with a coating of PVC 0·014 in. thick—can be supplied in a variety of colours and sizes (sheets up to 12 ft long and 4 ft wide). It can be bent, formed, seamed, and deep-drawn without damaging the coating; it is also possible to join and weld it. The many applications of the material on display well illustrated the versatility of Stelvetite.

Tinplate in coils

The first coils of tinplate ever to be produced in the UK have been made at the Velindre Works of The Steel Company of Wales Ltd. So far about 100 tons of strip tinplate in coil form have been despatched to customers.

When the No. 2 electrolytic tinning line was installed at Velindre it was equipped with twin recoilers situated immediately following the drive bridle. These have now been brought into use and are ready to supply the demand for coils that is expected to increase as more users of tinplate equip their works with coil-handling equipment.

For the tinplate users there are a number of advantages in being able to obtain tinned strip. It lends itself more readily to continuous processes and allows considerable economy. In addition, strip is easier to handle, as it is possible to pick up in one coil the equivalent weight of five or six loaded stillages of cut plate.

From the production point of view there are also a number of advantages. Better continuity increases the speed of production, and the minor troubles encountered in cutting and classifying sheets at the end of the electrolytic line are avoided.

Adjustments required to change over the line to coil production have been reduced to a straightforward routine, after which the operations proceed at an increased speed. Strip passing through a down and upcut shears is cut and deflected down a conveyor to the recoiler, where a belt wrapper causes it to coil around a collapsing mandrel. The strip is then recoiled at speed until the required size of coil has been built up. Pushbutton control is then sufficient to shear the strip, and deflect the leading end into another conveyor leading to the second recoiler without actually stopping the line.

The recoilers are equipped with Askania edge control which causes each mandrel to be moved hydraulically to follow any direction of one edge of the strip. This provides coils with good uniform sides.

New plant at Consett

New plate rolling and finishing plant worth over £4½ million is to be built for the Consett Iron Co. Ltd. by Davy and United Engineering Co. Ltd. It will consist of a 39 in. and 60 in. × 132 in. four-high hot rolling mill, with a full range of auxiliaries, supplemented by plate-finishing equipment comprising heavy and light shearing lines. Steel plate will be produced up to 10 ft wide and 90 ft long.

The new plant is scheduled to start operations in mid-1960.

Another walking dragline

Erection of a £396 000 walking dragline is in progress at the Yarborough ironstone quarry, Scunthorpe, of the Ore Mining Branch of The United Steel Companies Ltd. The 790-ton machine (a W600) is expected to begin work in June. It has a 186-ft long jib, and its 10-yd³ bucket will enable it to strip 15 tons of overburden at each 'bite.' The ore will be removed by smaller mechanical diggers. Initially, the depth of overburden will be 30 ft, increasing as the quarry is exploited.

The W600 is the second machine of its kind in the Scunthorpe area, the previous one having been in operation at the Ore Mining Branch's Crosby Warren quarry for the past two years. When the new dragline starts work, the Yarborough quarry will be able to provide 36 000–40 000 tons of ore weekly for the Appleby-Frodingham blast-furnaces.

New techniques for tin

The Annual Report for 1958 on the work of the Tin Research Institute mentions many newly discovered facts about tin, its alloys, and chemical compounds that may be worth careful study by industry. Metal industries will find many items of interest, including the work on new alloys of tin with newer metals such as titanium. Tin–nickel plating is now being taken up by watch and instrument industries for which this plating has much to commend it.

The Institute continued its free technical advice services to firms and individuals all over the world. The Institute's branches in eight overseas countries participated fully in all this work.

Copies of the Report may be obtained free of charge from the Tin Research Institute, Fraser Road, Perivale, Greenford, Middlesex.

Erection of a blooming mill in record time

On 15th December, 1958, the erection of a new 48-in. blooming mill was completed at Stewarts and Lloyds Ltd., Corby. The new installation, which was supplied by Schloemann AG of Düsseldorf, was erected on the site of the former 40-in. mill. The old mill, which weighed 1 500 tons, was first dismantled, and the old foundations, consisting of 600 yd³ of concrete, had to be removed. A new concrete foundation totalling 920 yd³ was then laid, and the new installation, weighing 1 750 tons, was erected.

From the time the last ingot was rolled in the old mill until the first ingot entered the new stand, exactly 10 days and 10 hours elapsed. This is believed to be the shortest time for such an operation anywhere in the world.

The new mill is capable of rolling ingots weighing 5–7 tons, and has a potential annual production of 1·5 million tons.

Information conference at Sheffield

An information conference is being held at the Central Library Theatre, Sheffield, at 2.30 p.m. on 23rd April. It is designed to make better known the facilities that exist for local firms to obtain access to up-to-date information on problems of techniques, management, and organization, and to hear the views of the firms on these problems.

The conference is supported by the British Iron and Steel Federation, BISRA, BSCRA, The Iron and Steel Institute, the Sheffield Chamber of Commerce, and the Sheffield City Libraries. Invitations to attend have been sent to the senior management of companies in the Sheffield area.

Forging press order

An order has been placed with Davy and United Engineering Co. Ltd. by Brown Bayley Steels Ltd. for a 1 500-ton hydraulic forging press. The press will be of the single cylinder four-column type, complete with hydraulic tool-changing gear. There are two particular points of interest in its design. It will be operated from a direct oil pump drive of the "Towler" Electraulic type, the first application in the UK of this type of drive to a forging press of such a size. It will also be one of the first presses to be equipped with automatic position control: this enables the movement of the press crosshead to be automatically stopped at any preset point on the downwards or upwards stroke, without any necessity for corresponding action on the part of the press operator.

The press will be installed in the Leeds Road Works, Sheffield, of Brown Bayley's and is due for delivery in December, 1959. It will be built in the Glasgow Works of Davy-United.

Replacement of welding equipment

Quasi-Arc Ltd. have introduced a scheme for replacing automatic welding machines. Self-propelled Fusarc and Fusarc/CO_2 machines can now be returned within nine years of purchase, and a fully reconditioned machine will immediately be delivered from stock. The reconditioned machines will also be of the latest Mark III type and will carry the company's normal 12-month guarantee. The price is fixed regardless of the condition of the returned machine, provided that it is complete, but will vary slightly, depending on its age and the model.

Changes of Address and Title

D.M.M. (Machinery) Ltd. and Mannex (London) Ltd. have moved to Universal House, 60 Buckingham Palace Road, London S.W.1 (SLOANE 0701).

The Phoenix Iron and Steel Company of Phoenixville, Pa., USA, has changed its name to the Phoenix Steel Corporation.

The telephone number of Vickers Armstrong (Engineers) Ltd. of Crayford, Kent, is now Crayford 26222.

High Duty Alloys Ltd. have opened a new Midland Area Sales Office at Queen's College Chambers, 38a Paradise Street, Birmingham 1 (Midland 3286).

Alexander Samson Ltd., UK agents for the Austro-American Magnesite Company and the International Magnesite Company, have moved to 9 Grosvenor Road, Southport (telephone 66212); they are now also sole UK agents for the General Refractories Company, of Philadelphia.

The offices and works of Grades Metals Ltd. have been transferred to Steel House, Hanworth Lane, Chertsey, Surrey (telephone Chertsey 2101).

The London office of Sunvic Controls Ltd. is now at Crown House, Aldwych, London W.C.2 (TEMPLE Bar 8040).

DIARY

2nd Apr.—LEEDS METALLURGICAL SOCIETY—"*Special steel manufacture*," by D. Hall—Low Moor Alloy Steelworks Ltd., Bradford, 7.15 p.m.

2nd–3rd Apr.—METALLURGICAL SOCIETY OF AIME—Conference on the physical metallurgy of stress-corrosion fracture—Mellon Institute, Pittsburgh, Pa., USA.

3rd Apr.—LINCOLNSHIRE IRON AND STEEL INSTITUTE—26th Annual Dinner.

5th–10th Apr.—AMERICAN CHEMICAL SOCIETY—135th Meeting—Boston, Mass., USA.

6th Apr.—CLEVELAND INSTITUTION OF ENGINEERS—"*Iron and steel works maintenance*," by A. V. Williams—Cleveland Scientific and Technical Institution, Middlesbrough, 6.30 p.m.

6th–12th Apr.—5th METALLURGY-SKIING MEETING—St. Christoph am Arlberg, Tyrol, Austria.

7th Apr.—EAST MIDLANDS METALLURGICAL SOCIETY—Annual General Meeting and "*Metallurgical examination of failures*," by G. A. Cottell—Electricity Lecture Theatre, Carrington Street, Nottingham, 7.30 p.m.

8th Apr.—INSTITUTION OF ENGINEERING INSPECTION—"*Control and inspection of resistance-welding*," by C. L. Railton—Birmingham Exchange and Engineering Centre, 6.30 p.m.

9th Apr.—LIVERPOOL METALLURGICAL SOCIETY—11th Annual General Meeting, and "*Boron in steel*," by F. B. Pickering—Department of Metallurgy, University of Liverpool, 7 p.m.

10th Apr.—BRITISH NUCLEAR ENERGY CONFERENCE—"*Some highlights of high-power heavy-water moderated nuclear reactors*," by Dr. W. B. Lewis (James Clayton Lecture)—Institution of Mechanical Engineers, 1 Birdcage Walk, London S.W.1, 6 p.m.

10th Apr.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—Symposium on open-hearth maintenance—39 Elmbank Crescent, Glasgow, 6.45 p.m.

12th–14th Apr.—NATIONAL ACADEMY OF SCIENCES—Conference on atomic mechanisms of fracture—Swampscott, Mass., USA.

14th–16th Apr.—INSTITUTE OF METALS—Spring Meeting—Church House, Great Smith Street, London S.W.1.

15th Apr.—INSTITUTE OF METALS—Dinner-Dance.

14th–17th Apr.—THE IRON AND STEEL INSTITUTE (Iron and Steel Engineers Group)—Meeting on ore handling—Holland.

16th–30th Apr.—22nd ENGINEERING, MARINE, WELDING AND NUCLEAR ENERGY EXHIBITION—Olympia, London.

20th–24th Apr.—INSTITUTE OF WELDING—Spring Meeting—54 Princes Gate, London S.W.7.

20th Apr.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Film night—Sheffield University, 7.30 p.m.

23rd Apr.—NORTH-EAST METALLURGICAL SOCIETY—Annual General Meeting—Cleveland Scientific and Technical Institution, Middlesbrough, 7.15 p.m.

24th Apr.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Biennial Dinner—Royal Victoria Hotel, Sheffield—6.45 for 7.30 p.m.

25th Apr.–10th May — 11th LIÈGE INTERNATIONAL FAIR—Liège, Belgium.

27th–30th Apr.—CORROSION EXHIBITION—Royal Horticultural Society's New Hall, London S.W.1.

28th Apr.—BRITISH IRON AND STEEL FEDERATION—Conference on crane safety—Connaught Rooms, Great Queen Street, London W.C.2., 10 a.m.

29th–30th Apr.—INSTITUTION OF ELECTRICAL ENGINEERS (British Nuclear Energy Conference)—Convention on thermonuclear processes—Savoy Place, London W.C.2.

29th Apr.—POWDER METALLURGY JOINT GROUP—Informal discussion on "Theoretical aspects of sintering"—Church House, Westminster, London S.W.1., 9.30 p.m.

6th May—SOCIETY OF CHEMICAL INDUSTRY (Corrosion Group)—Annual General Meeting and Chairman's Address, by Dr S. G. Clarke—14 Belgrave Square, London S.W.1, 6.30 p.m.

6th–7th May—THE IRON AND STEEL INSTITUTE—Annual General Meeting—Church House, Great Smith Street, London S.W.1.

6th May—THE IRON AND STEEL INSTITUTE—Dinner for Members—Grosvenor House, Park Lane, London W.1.

7th–9th May—INSTITUTE OF METALS—Residential meeting on "Design and operational aspects of melting furnaces in the non-ferrous metals industry"—Ashorne Hill, Leamington Spa.

7th May—LEEDS METALLURGICAL SOCIETY—Annual General Meeting and "Electric melting furnaces," by F. S. Leigh—Chemistry Wing, University of Leeds.

9th May—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Annual General Meeting—Central Library, Swansea, 6.30 p.m.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 396 of the March, 1959, issue of the journal:

1052. STÄBLEIN, H., and H. MÖLLER: "Recrystallisation Textures of Cold Rolled Transformer Steel." *Arch. Eisenhütt.*, 1958, July, pp. 433–447. (£8 5*s*. 0*d*.)

1099. BORISOV, S. I.: "The Consumption and Economy of Power in the Production of Tubes by the Automatic and Pilger Processes." *Stal'*—Rolling and Tube Manufacture Supplement, 1958, pp. 314–337. (£5 15*s*. 0*d*.)

1116. ZUSMAN, L. L.: "Economic Advantages of Producing Lightened-section Rolled Products." *Stal'*, 1956, Dec., pp. 1099–1103. (£4).

1117. FEIGIN, G. D.: "Comments on L. L. Zusman's Paper 'Economic Efficiency of Rolling Light Sections'". *Stal'*, 1958, July, pp. 652–653. (£1 10*s*. 0*d*.)

1132. ZINOV'EV, N. V.: "Modern Hot-blast Cupolas for Steelworks." *Stal'*, 1958, Sept., pp. 796–799. (£3 5*s*. 0*d*.)

1140. RELLERMEYER, H., and R. HAMMER: "Metallurgical Problems Encountered in the Pouring and Solidification of Rimming Steel." *Stahl u. Eisen*, 1958, Oct. 30th, pp. 1505–1513. (£7)

1149. POGGIO, J. A. Garcia: "The Use of Steels at High Levels of Tensile Strength." *Tecnica Metallurgica* (Barcelona), 1957, Jan./Feb., pp. 1–43. (£10)

1152. NEUHAUS, H., and H. SCHENCK: "Chlorination of Ore Fines during Sintering." *Stahl u. Eisen*, 1958, Nov. 13th, pp. 1662–1670. (£6 10*s*. 0*d*.)

1157. PITSCH, W., and A. SCHRADER: "The Form of Precipitation of ϵ-carbide in Ferrite and Martensite during Tempering." *Arch. Eisenhütt.*, 1958, Nov., pp. 715–721. (£5 10*s*. 0*d*.)

1158. KRISEMENT, O.: "The Kinetics of the Tempering of Martensite." *Arch. Eisenhütt.*, 1958, Nov., pp. 723–729. (£5).

1160. HOŘEJŠ, S.: "A Contribution to the Problem of the Formation of Longitudinal Cracks in Rail Flanges after Straightening." *Hutnické Listy*, 1958, June, pp. 517–526. (£8 15*s*. 0*d*.)

1162. EFROIMOVICH, Yu. E., *et al.*: "A Computer for Controlling the Parameters of an Arc Furnace." *Elektrichestvo*, 1958, (5), pp. 15–20. (£5 10*s*. 0*d*.)

1165. RABOTNOV, B. A.: "The Impact Strength of the Metal of the Heat-affected Zone of Welded Joints in High-chrome Steel." *Avtom. Svarka*, 1958, (9), pp. 20–23. (£3)

1166. SLUTSKAYA, T. M., and V. G. GORDONNY: "Research into New Types of Low-alloy Steel for Welded Structures." *Avtom. Svarka*, (9), pp. 3–12. (£5 10*s*. 0*d*.)

1168 ADABASCHJAN, A. K.: "Measuring Roof. Temperature in the Open-hearth Furnace by means of a Photo-electric Pyrometer." (Abridged). *Neue Hütte*, 1958, Oct., pp. 615–619. (£2 10*s*. 0*d*.)

1169. KOVAL'CHUK, E. I., and G. I. POPOV: "Life of the Open-hearth Furnace Refractory Lining when Using Oxygen." *Stal'*, 1958, Oct., pp. 890–893. (£2 15*s*. 0*d*.)

1171. BERGLUND, T.: "Grain-size Charts for Ferritic Austenitic Structures." *Jernkontorets Ann.*, 1953, (11), pp. 767–784. (£3 15*s*. 0*d*.)

1173. BERDYANSKII, M. G.: "The Mechanisation and Automation of Tube Production." *Stal'*, 1958, Oct., pp. 928–930. (£3 5*s*. 0*d*.)

1175. TETERIN, P. K.: "Contribution to Problems concerning the Kinematics Considerations of the Cross and Oblique Rolling Processes." *Stal'*, 1958, Oct., pp. 923–925. (£3 5*s*. 0*d*.)

1178. HAARMANN, R., and D. HORSTMANN: "Distribution and Effect of Aluminium in an Industrial Sheet Galvanising Bath." *Stahl u. Eisen*, 1958, Dec. 11th, pp. 1808–1811. (£2 15*s*. 0*d*.)

1187. ANTONI, H.: "Accidents in the German Iron and Steel Industry in 1957 (Works Accident Statistics) with Comparative Data from the American, British, Japanese, French, and Austrian Iron and Steel Industries." *Stahl u. Eisen*, 1958, Dec. 25th, pp. 1891–1898. (£3 15*s*. 0*d*.)

1188. STOROZHEV, M.: "Elementary Theory of Plastic Deformation." *Vestnik Mashinostroeniya*, 1948, (5), pp. 43–48. (£2 15*s*. 0*d*.)

1189. GUEUSSIER, A., and R. CASTRO: "Experimental Study of Hot Deformation of Steels and Alloys" (with discussion and bibliography). *Rev. Mét.*, 1958, Nov., pp. 1023–1041. (£10)

1190. MATHEA, A.: "Nomograms for the Determination of Roll Force, Based on the Equation of S. Ekelund." *Stahl u. Eisen*, 1958, Oct. 2nd, pp. 1383–1389. (£3 5*s*. 0*d*.)

1193. RED'KO, A. N.: "Utilisation of Manganese when operating the Blast-furnace on Oxygen-enriched Blast." *Metallurg*, 1958, Sept., pp. 7–10. (£2 10*s*. 0*d*.)

1195. MELDAU, R.: "Wetting Agents in Dust Techniques with Special Regard to the Wetting of Finely Divided Iron Oxides in Steelworks' Smoke." *Arch. Eisenhütt.*, 1957, Oct., pp. 615–621. (£4 5*s*. 0*d*.)

1201. MUT'EV, M. S.: "Definition of the Oval Pass Area." *Stal'*, 1958, Sept., pp. 823–824. (15*s*.)

1218. KOROBOV, P. I.: "Towards Fulfilling the Tasks Laid Down by the Party." *Stal'* 1958, Dec., pp. I–IV. (£4 5*s*. 0*d*.)

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

CONTENTS

Note—The letters *a*, *b*, and *c* refer to the three columns of the page concerned.

	PAGE
MINERAL RESOURCES	395*a*
ORES—MINING AND TREATMENT	395*a*
FUEL—PREPARATION, PROPERTIES, and USES	396*a*
AIR POLLUTION AND SMOKE	396*a*
TEMPERATURE MEASUREMENT AND CONTROL	396*b*
REFRACTORY MATERIALS	396*b*
IRON AND STEEL, GENERAL	397*b*
BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON	397*c*
PROPERTIES, TREATMENT AND USE OF SLAGS	398*c*
DIRECT PROCESSES	398*c*
PRODUCTION OF STEEL	399*a*
PRODUCTION OF FERRO-ALLOYS	400*b*
FOUNDRY PRACTICE	400*b*
VACUUM METALLURGY	401*b*
REHEATING FURNACES AND SOAKING PITS	401*c*
HEAT-TREATMENT AND HEAT-TREATMENT FURNACES	402*a*
FORGING, STAMPING, DRAWING AND PRESSING	403*b*
ROLLING MILL PRACTICE	403*c*
MACHINERY AND SERVICES FOR IRON AND STEEL PLANT	404*c*
WELDING AND FLAME-CUTTING	404*c*
MACHINING AND MACHINABILITY	405*b*
CLEANING AND PICKLING	405*c*
PROTECTIVE COATINGS	406*a*
POWDER METALLURGY	406*b*
FERRITES, CERMETS AND CARBIDES	406*b*
PROPERTIES AND TESTS	406*c*
METALLOGRAPHY	410*b*
CORROSION	411*b*
ANALYSIS	413*a*
INDUSTRIAL USES AND APPLICATIONS	414*b*
HISTORICAL	414*c*
ECONOMICS AND STATISTICS	415*a*
MISCELLANEOUS	415*a*
BOOK NOTICES	415*b*
NEW PUBLICATIONS	416*b*

*Abstracts, the reference to which is marked with an asterisk are, or are to be made available as translations.

MINERAL RESOURCES

Iron Ore. H. T. Reno. (*U.S. Bur. Mines, Min. Yearbook*, 1956, **1**, 581–612). Mainly statistical.

The Main Iron Ore Deposits of the U.S.S.R. I. S. Shapiro. (*Metallurg*, 1958, (9), 1–3). This is a most useful brief survey with figures of ore production according to type, and geographical distribution.—R. S.

Transition of Martite Ores into Magnetite Ores in the Saksagan Region of the Krivoi Rog Basin. Yu. P. Mel'nik. (*Doklady A. N.*, 1958, **120**, (5), 1095–1098). The intensely folded quartz-magnetite and silicate-magnetite ores of this region in their upper zone are oxidized and transformed into martite ores. Seven chemical analyses of iron ores are given.—S. I. T.

The Discharge of Iron in Solution into the Okhotsk Sea from the Thermal Springs of Ebeko Volcano of Paramushir Island. K. K. Zelenov. (*Doklady A. N.*, 1958, **120**, (5), 1089–1092). Volcanic thermal springs on one of the islands of the Kurile group form three rivers the waters of which are very acid and very rich in dissolved ferrous iron. On reaching the sea these waters discharge an abundant flocculent precipitate of ferric iron which eventually settles down at the bottom of the sea.—S. I. T

ORES—MINING AND TREATMENT

The Future Supplies of Iron Ore for Europe. A. Bureau. (*Mém. Soc. Ing. Civils France*, 1958, **111**, July-Aug., 287–299).

Iron Ore: A Slow Year Points Up Changing Supply Pattern. T. M. Rohan. (*Iron Age*, 1958, **182**, Sept. 11, 175–177). Lake Superior shipments have been greatly reduced in a year of slack demand through competition from pelletized taconites and imported ores. Next year, volume shipments of Labrador ores will add to this competition.—A. G.

New Source for Iron Ore. (*Steel*, 1958, **143**, Sept. 22, 88). At the International Nickel Co's plant at Copper Cliff, Ontario, iron concentrate with 63% Fe and 0·15%Ni is recovered from the nickel ore slag. The process used, based on fluidized roasting and reduction, with magnetic separation is described.—A. G.

Exploration, Development and Costs of the Stormy Day Tungsten Mine, Pershing Co. Nev. A. C. Johnson. (*U.S. Bur. Mines Inf. Circ.* 7854, 1958, pp. 9).

The Transport and Handling of Materials in Mines. H. Ahlmann. (*Jernkont. Ann.*, 1958, **142**, (8), 473–514). Mechanization in Swedish mines, maintenance, organization, and statistical and purchase-policy methods are described.

Chemical Solidification of Soil in Tunneling at a Minnesota Iron-Ore Mine. R. O. Pynnonen and A. D. Look. (*U.S. Bur. Mines Inf. Circ.* 7846, 1958, pp. 8). Sodium silicate—$CaCl_2$ injection was used successfully against a water-laden sand bed.

The Softening Temperature of the Chiaturskii Manganese Ores. M. A. Kekelidze. (*Stal'* 1958 *supplement* "*Blast Furnace Production*," *Metallurgizdat*, 1958, 138–142). Tests are described in which the softening temperatures of these ores were determined on a special apparatus. Various qualities or ores and sinters with a Mn content ranging between, 22·76% and 56·91% were investigated and the results plotted on graphs.—L. H.

Ore Agglomeration with Limestone, Ore-Fines and Sludges. R. Forbath and I. Raabe. (*Koh. Lapok*, 1958, **13**, May-June, 241–250). Hungarian ore agglomeration experiments are described employing Russian red iron ore, blast furnace dust, calcined pyrites, red mud, limestone, dolomite, cinder and coke.—P. K.

Industrial Production and Metallurgical Treatment of Ore-Lime-Coke Briquettes. K. Säuberlich and W. Zwade. (*Neue Hütte*, 1958, **3**, Oct., 594–602). A description is given of a process for the production of iron-fine ore briquettes on roll presses developed by the Pig Iron Research Institute (Forschungsstelle für Roheisen). Unlike sintering, the process involves no heat treatment, unlike pelleting, it is largely independent of the properties of the raw materials.—L. J. L.

Fundamental Studies on Briquetting Ore-Lime-Coke Mixtures. K. Säuberlich, G. Richter, and W. Zwade. (*Neue Hütte*, 1958, **3**, Sept., 533–541). Results are reported of extensive briquetting tests with ores using Buna limestone as a binder and adding coke as a reduction medium. The experimental apparatus is described; the chemical, physical, and petrological properties of the raw materials used are listed; optimum grain size, moisture content, briquetting pressure, and binder-and-coke contents are given. It is shown that it is possible to obtain from native ores of 0–2 mm particle size with 10% Buna limestone and 10% coke, and at a pressure of 700 Kg/cm², briquettes that, following thermal treatment for 90 mins at 250° C, are suitable for use in the low-shaft furnace.—L. J. L.

Mix is Key to Better Sinter. (*Steel*, 1958, **143**, July 21, 120–122). The new 5000-t per day sinter plant at Youngstown, Ohio, uses two 18 ft "flying saucers" for mixing and pelletizing the feed. Other features are the use of a hearth layer and a forced air cooler.—A. G.

Experiences with the Sintering of Weak Krivorozhskii Ore Concentrates at the Southern Ore Enriching Combine (YuGOK). D. I. Uryupin. (*Stal'* 1958, *supplement* "*Blast Furnace Production*," *Metallurgizdat*, 1958, 60–66). After a full description of the preparation of the burden for sintering, of the plant available and of the sintering process itself, some conclusions are drawn among which are the need for reducing the moisture content of the concentrates to 7–8% and a more stringent control of returns (up to 40%).—L. H.

Sintering of Fluxed Krivorozhskii Ores. T. A. Kramnik. (*Stal'* 1958, *supplement* "*Blast Furnace Production*," *Metallurgizdat* 1958, 44–59). The fluxed sinter of a low basicity of the order of 0·5–0·9 of the Krivorozhskii ores has been successfully utilized. The main difficulty in sintering resides in the large additions of limestone needed for fluxing the acid gangue (approximately 12–14%SiO_2). This requires 16–19%CaO for a basicity of 1·4. The main advantages of the process of fluxing lie in an increase in the sintering rate which results in a very high gaseous permeability in the combustion zone. The lower basicity also reduces the FeO content and thus influences the hardness of the sinter.—L. H.

Reducing Power of Magnitogorsk Sinters. N. L. Gol'dshtein and N. S. Khromchenko. (*Stal'* 1958, *supplement* "*Blast Furnace Production*" *Metallurgizdat* 1958, 3–15). Powdered sinter obtained by crushing the original

coarse-grained material has many advantages and since the ratio of the reducing power of the coarse and the fine-grained specimens is nearly constant, the powdered specimen can always be substituted in analysis. A method using a special apparatus is described by which one can complete a rapid analysis in a fraction of the time needed for the conventional methods (only 30–35 minutes). Experiments have shown that an increase in basicity without an appropriate sintering process does not improve the reducing capacity and that variations in the FeO content exercise a great influence. The relation between the degree of reducing power and the quotient Fe++/Fe total in the sinter is very sensitive, hence the decisive role played by the heating process and the composition of the sinter in the burden.—L. H.

Industrial Method for Determining the Reducing Power of Sinter. T. A. Kramnik. (*Stal'* 1958 *supplement* "*Blast Furnace Production*" *Metallurgizdat* 1958, 16–25). The "Standard-Express" method at the Magnitogorsk Metallurgical Combine of determining the reducing power of sinter by the escaping gases in a horizontal furnace requires 4–6 h and a great deal of equipment, and does not correspond to the results under conditions of production. The proposed method carries out the reduction reaction in a current of hydrogen in a vertical furnace, according to the method worked out by Prof. A. N. Pokhvisnev as used at the Dzerzhinskii works with specimens weighing up to 100 g and which requires only 30–40 minutes. It only requires simple equipment and can be used in any laboratory.—L. H.

Efficient Industrial Control Method of the Reducing Power of Sinter. A. G. Neyasov. (*Stal'*, 1958, *supplement* "*Blast Furnace Production*" *Metallurgizdat*—1958, 26–43). The amount of oxygen removed from a weighed specimen of the sinter can be determined either directly by difference between the weight of the specimen before and after reduction or by calculation from the average amount of CO_2 in the gaseous products of reduction and from the amount of the gaseous reducing agents consumed in the reaction according to a given formula. A special apparatus for carrying out the analysis is described and a full account is given of the method, which permits the simultaneous determination not only of the hardness, but also of the reducing capacity of the sinter for each batch in the hoppers with sinter.—L. H.

FUEL—PREPARATION, PROPERTIES AND USES

Mechanical Cleaning of Coal. P. J. Vanc Der Walt. (*South African Mech. Eng.*, 1958, **8**, Sept., 43–55). A review.

Coal Mixed en Route to Ovens. (*Steel*, 1958, **143**, Aug. 18, 104–108). The blending system for Jones and Laughlin's Vesta and Shannopin coking coals is described. The Vesta coal comes from the local mine by conveyor in which there is a weigh-scale; the flow of the other fuel from surge-bins is automatically controlled to be proportional to that of the former.—D. L. C. P.

The Production of Metallurgical Coke in Hungary. B. Tóth-Sarudy. (*Koh. Lapok*, 1958, **13**, May-June, 227–236). The paper contains a detailed description of Hungarian metallurgical coke production.—P. K.

Assessment of Hard Coke Requirement in India. A. Lahiri, A. Ghosal and N. C. Sinka. (*Iron Steel Rev.*, 1958, **1**, Mar., 19–26). Estimates of the total requirement, not for steel plants alone, are given.

AIR POLLUTION AND SMOKE

The "Clean Air" Problem with Particular Reference to Foundries. Especially Steel Works. II. K. Guthmann. (**Radex Rundschau*, 1958, Sept., 253–276). The following are discussed: waste gases and air-borne dust in O.H. furnaces; emission, concentration, and chemical composition; the use of O_2 in O.H. furnaces; operating experience in U.S. Steel Works with various types of dedusting equipment (wet scrubbers, slag wool filters, electrostatic precipitators); ventilation of steel works.

Air Pollution and New Trends in Purification of Industrial Gases. B. Maczewski-Rowiński. (*Prz. Techn.*, 1958, Aug., 705–710). [In Polish]. Harmful effects of air pollution by industrial wastes are discussed; examples of economic losses are quoted. Some figures concerning sedimentation in a few industrial areas of Poland are given. Shortcomings of old methods of gas purification are briefly described. New trends in this field are: use of ultrasonic sirens and venturi nozzles. Their main advantage is the ability to eliminate the smallest dust particles, (1μ and less), which are most dangerous. Some foreign devices are described. A brief description of experiments with sirens and venturi nozzles which are being carried out in Poland, is given.

Dust in Metallurgical Works. M. Havelka. (*Hutn. Listy*, 1958, **13**, (9), 778–785). The author outlines the problems associated with dust in iron and steel works, especially from steam boilers, sinter plants and blast furnace gases. He analyses all the sources of dust in his own works, which he totals at about 60 lbs dust/t pig-iron. He assesses that by modern methods it is possible to reduce the amount of dust by 50%.—M. T.

Installation of a Dust Collecting System at the L. D. Donawitz Steelworks. Schertler and Futschek. (*Acier-Stahl-Steel*, 1958, **23** Oct. 435–436). A brief description, with diagram, of the Lurgi electrostatic dry deduster built for the top-blown converter plant.

Dust Removing Plant at the Donawitz Steelworks. Schwertler and Futschek. (*Acier-Stahl-Steel*, 1958, **23**, Oct. 437–438). A brief description of the electrostatic plant with special reference to framing and support.

TEMPERATURE MEASUREMENT AND CONTROL

The Measurement of Gas Stream Temperatures in Industrial Appliances. II.—A Suction Pyrometer for Temperatures above 1100° C. P. G. Atkinson and J. R. Hargreaves. (*Gas Council Res. Commun.* GC57, 1958, pp. 30).

Results of Radiation Measurements on Flames in Open-Hearth Furnaces. H. Schicke. (*Neue Hütte*, 1958, **3**, Oct., 622–629). Total radiation from the soot in the flame, and the temperature of the flame, can conveniently be recorded by the Naeser colorimetric pyrometer. The results can be interpreted or plotted in different ways, depending on the nature of the problem: examples are given. The effects on temperature and mean emissivity of the producer gas flame of the addition of long-distance gas, of oil carburization, and of gas preheating have been investigated.

Roof Temperature Measurements in Open-Hearth Furnaces Using a Photoelectric Pyrometer. A. K. Adabaschjan. (*Neue Hütte*, 1958, **3**, Oct., 615–619). Design, construction and testing of a photoelectric immersion pyrometer are described.—L. J. L.

REFRACTORY MATERIALS

Gap Between Basic Knowledge and Its Application in the Use and Manufacture of Refractories. H. K. Mitra. (*Indian Construction News*, 1958, Feb., 148–154). Theoretical knowledge and its application to steelworks refractories are discussed.

New Aspects on the Mineralogical Composition of Silica Bricks, Especially Concerning the So-called Vitreous Phase. O. W. Flörke. (*Silicates Ind.*, 1958, **22**, Oct., 497–501). The author discusses results obtained for establishing the existence of the "glass-phase" at room temperature. Methods used involved X-rays, the determination of the rate of crystallization of the ternary eutectic Al_2O_3–CaO–SiO_2 and phase-contrast microscopy of thin sections of silica bricks. About 5% of glass-phase exists in a modern silica brick and this may be insufficient either for binding the silica grains or for the formation of tridymite.—R. P.

Investigation of Refractory Magnesite Bricks. Sa Fe, Tan Ko-Chan, Huy Yu-Tao, Mao Dun-Syn, Sou Lian-In. (*Acta Metallurgica Sinica*, 1957, **2**, (3), 273–287). Following experiments in the laboratory and on a semi-industrial scale, standard refractory magnesite bricks were produced, porosity 18%, deformation temperature under load 1510–1520° C and thermal shock resistance (water cooling, average) 107, i.e. a better quality than that of chrome–magnesite bricks. Means were also found further to increase quality by using coarse-grained spinels in proportions between 10 and 30%. Any alumina additions increase the shock resistance of the magnesia.—L. H.

A New Refractory: Aluminium Nitride. M. Rey. (*Silicates Ind.*, 1958, **22**, Sept., 453–455). Although AlN was used some time ago as a refractory constituent, the trials described are thought to represent the first use as the sole constituent of a refractory. Physical properties and method of manufacture of the refractory are given.

Investigations into the 4-Component System MgO–FeO–Fe_2O_3–Al_2O_3. A. Cocco. (*Radex Rundschau*, 1958, Sept., 282–291). Equilibrium conditions of this quaternary system at 1600° C have been investigated by microscopy and X-radiography. The results confirm the existence of a solid quaternary solution and explain the occurrence of zonal structures previously reported in the separation of periclase granules.—L. J. L.

Crystal Chemistry and Refractories. Y. Letort. (*Indian Construction News*, 1958, Feb., 14–20). A discussion of the relationship between the crystallography of refractories and their properties, with reference to specific examples.

A Metallurgist Looks at Refractories Research. E. H. Bucknall. (*Indian Construction News*, 1958, Feb., 22–25). The properties of the principal industrial refractories are summarized, and current lines of research are outlined.

India's Resources in Refractory Materials. M. S. Krishnan. (*Indian Construction News*, 1958, Feb., 26–29). India's resources in graphite and in silica, fireclay, magnesite, dolomite and other refractory raw materials are described.

Recent Trends in Winning and Preparation of Refractory Raw Materials. A. Banerjee. (*Indian Construction News*, 1958, Feb., 30–31). Some modern Indian trends in the winning and treatment of fireclays are outlined.

Recent Trends in Production of Alumino-Silicate Refractories. N. S. Rao. (*Indian Construction News*, 1958, Feb., 32–36; discussion 37–38). Various stages in the production of Al_2O_3–SiO_2 refractories are described, with special reference to Indian conditions.

Recent Trends in Production of Silica Refractories. J. Hammond. (*Indian Construction News*, 1958, Feb., 39–41). Modern developments in the production of SiO_2 brick and shapes are described, reference being made to Indian practice.

Recent Trends in Production of Basic Refractories. D. R. Subramanian. (*Indian Construction News*, 1958, Feb., 42–45; discussion 45). The sources and methods of production of basic refractories are outlined, some typical properties being tabulated.

Modern Tunnel Kilns for Firing Refractories. R. G. Le Grip. (*Indian Construction News*, 1958, Feb., 46–53; discussion 53–54), Several recently designed tunnel kilns are described; construction and operation are discussed, and diagrams and photographs are reproduced

Modern Trends in the Field of Refractories for Iron and Steel Industry. L Halm (*Indian Construction News*, 1958, Feb , 55–73; discussion 73) The refractories used in French practice in blast furnaces, hot blast stoves, ladle bricks, stoppers etc., and bottom teeming brick are discussed in detail. (81 refs.).

Magnesia Refractory Materials for Martin (Open Hearth) Furnaces in the U.S.S.R. A. S. Berazhnoi. (*Indian Construction News*, 1958, Feb., 76–81). The increased working temperatures of Russian O.H. furnaces have led to the greater use of magnesite refractories. The main developments have been in the direction of increasing the purity of raw materials and in reducing porosity. Methods used in achieving these properties are discussed.

Silica Bricks in the Siemens-Martin Furnace. K. Konopicky. (*Indian Construction News*, 1958, Feb., 82–85). Experiments in the use of SiO_2 brick O.H. refractories are described and discussed. It was found that Al_2O_3, porosity and permeability should be kept to a minimum. The effect of TiO_2 and alkali contents is discussed.

Recent Trends of Refractories Used in Metal Industries in Japan. T. Yamauchi. (*Indian Construction News*, 1958, Feb., 86–92; discussion 92). The production and classification of Japanese refractory bricks is given, and the use of indigenous materials discussed.

Studies on Graphite Refractories. T. Yamauchi and H. Suzuki. (*Indian Construction News*, 1958, Feb., 105–120; discussion 120–121). The properties of indigenous graphite and its use for the manufacture of graphite crucibles and casting pit refractories are described, with reference to the use of admixed SiC.

Influence of Mineralogical Composition and Manufacturing Process of Aluminous Refractory Products on Their Resistance to Corrosion. Y. Letort. (*Indian Construction News*, 1958, Feb., 123–134; Discussion 134–135). An investigation is described with the object of determining the raw materials and method of manufacture most suitable for refractory products which are required to resist corrosion by blast furnace and O.H. slags.

Trends in Techniques in Research on Refractories. J. B. Austin. (*Indian Construction News*, 1958, Feb., 140–142). The use of new methods of physical and chemical examination, and of statistical methods in refractories research is outlined.

Solid State Reactions in Refractories Research. V. D. Frechette. (*Indian Construction News*, 1958, Feb., 143–147). The principal types of solid state reactions are outlined, and their applications to refractories research discussed briefly. (69 refs.).

Technical Note on Dimensional Standardisation of Refractories. Rabindar Singh and H. P. S. Murthy. (*Indian Construction News*, 1958, Feb., 158–159). The necessity for dimensional standardization in the Indian refractories industry is emphasized, and the means by which this may be achieved are discussed.

Refractories a Limiting Factor in Metallurgical Research. B. R. Nijhawan. (*Indian Construction News*, 1958, Feb., 155–157). Limitations imposed by refractories, particularly in the preparation of pure metals are discussed, with reference to the production of pure titanium.

Permeability and Cohesion of Silica–Alumina Refractories for Blast Furnaces. P. Guyot. (*Silicates Ind.*, 1958, **22**, Oct., 508–517). After reviewing general requirements to be met by silica–alumina linings for blast furnaces, the author describes experiments regarding cohesion and permeability as a criterion for suitability. Variations in cohesion and permeability are a measure of resistance to thermal shock. Permeability and cohesion are stated to be mathematically related.—R. P.

A New Method of Studying the Chemistry of the Solid State and Its Application to the Problems of the Silicate Industries. Part I. W. A. Weyl. (*Silicates Ind.*, 1958, **22**, June, 309–315). A description is given of the theory of 'screening' (the need for positive ions to surround themselves with electrons) and Fajans theory of quanticles (where a quanticle is any entity which remains unchanged during a chemical reaction). A synthesis of these two theories provides a new approach to solid state chemistry.—A. G.

Precipitation of Giobertite and Dolomite from Solutions of Magnesium and Calcium Chlorides. G. Baron. (*Compt. Rend.*, 1958, **247**, Nov. 10, 1608–1611). Precipitation in a CO_2 atmosphere was studied.

IRON AND STEEL, GENERAL

The Influence of Transport on the Location of the Iron and Steel Industry. Pinot. (*Echo Mines*, 1958, Sept., 535–536). The Schuman Plan and the work of the High Authority are briefly considered.

The Iron and Steel Industries of Tomorrow in the Under-developed Regions. A. Guedras. (*Usine Nouv.*, 1958, **14**, Nov. 6, 38). French siliceous ores and direct reduction with natural gas are briefly considered.

The Iron and Steel Industry of Normandy. (*Usine Nouv.*, 1958, **14**, Nov. 13, 33, 35). A description of the Mondeville works of the Soc. Mét. de Normandie is given including the coke ovens, blast furnaces, converters and O.H. furnaces, rolling mills and wire-drawing plant.

Recent Trends in the Lorraine Iron and Steel Industry. J. E. Martin. (*Geography*, 1958, July, 191–199, reprint). Mainly statistical with an account of the effects of the European Coal and Steel Community.

Review of Metallurgical Technology. O. C. Ralston and E. T. Hayes. (*U.S. Bur. Mines, Min. Yearbook*, 1956, **1**, 45–53). A review of trends in the year including iron ore concentration and sintering and the Cyclosteel process.

Metallurgists' Day in the U.S.S.R. V. A. Podzerko. (*Metallurg*, 1958, **7**, 1–5). The Presidium of the Supreme Soviet decreed a new national holiday called "Metallurgists' Day" which will be celebrated annually on the third Sunday in July. This article reviews some of the highlights in Soviet metallurgy.—R. S.

Future Items in Soviet Iron and Steel Industry. B. N. Zherebinym. (*Metallurg*, 1958, **7**, 6–7). In this interesting interview with the general manager of the Kuznetsk plant, the following useful information is given: the blast furnace coefficient (working volume in m^3 required to produce 1-t of iron per 24 h) is down to 0·68; six more O.H. furnaces have been converted to hot-cooling this year; remote control of ladle stoppers by a hydraulic device has been achieved; vacuum treatment is being applied to transformer steel; sinter strand speed is automatically controlled; O.H. tap holes are opened automatically; a second blooming mill is to be built.—R. S.

Alchevsk Plant Fulfills Its Commitments. P. Gmyra. (*Metallurg*, 1958, **7**, 8–9). The general manager at Alchevsk enumerates plant and production developments since this plant was rebuilt from the 1943 ruins. These developments include intensive cooling of the blast furnace top when producing ferro-manganese so that inter-repair time was increased from 2 to 10½ years. The Alchevsk plant will soon be producing the cheapest steel in the Ukraine.—R. S.

Fifteen Years' Development at Chelyabinsk (Urals). G. I. Evchenko. (*Metallurg*, 1958, **7**, 10–11). This is a brief review of developments at Chelyabinsk since the building of the works in 1942 and of future plans up to 1965.

Orsko-Khalilovo Combine (South Urals). A. I. Sukhorukov and I. V. Arkhipov. (*Metallurg*, 1958, **7**, 12–13). This is a brief note on the new works at Novo Troitsk based on the deposits of iron ore naturally alloyed with Cr and Ni—the famous Khalil ore.—R. S.

The "Khazakstan Magnitogorsk" [The Karaganda Iron and Steel Plant]. A. P. Popov. (*Metallurg*, 1958, **7**, 13–16). This new plant is based on the coking coals of the Karaganda basin (Kazakhstan) and the newly discovered deposits of Atasuisk ores. This will be one of the gigantic plants of the "third metallurgical base" in the Soviet East. The blast furnaces will all operate on fluxed sinter, with blast temperature of 1200° C and on high top pressure of not less than 1·5 atm. Area of the sinter strands will be 7062 ft^2 each. Ingot weights will be 16·4 and 29 t. O.H. furnaces will be operated with oxygen and automatic control of heat input. Two continuous cold rolling mills are being built.

Yenakievsk Plant Fulfills Its Plan for the First Quarter of 1958. A. F. Minaev. (*Metallurg*, 1958, **7**, 17). This is a brief note on developments at the Yenakievsk plant which did not fulfill its 1957 plan. There is an interesting note on the difficulties associated with the building of the fourth blast furnace because of the slag and iron being tapped on the same side of the shop.—R. S.

Dnyeprodzerzhinsk Metallurgists. V. S. Sevast'yanov and S. S. Gurov. (*Metallurg*, 1958, **7**, 20–21). A brief, non-technical note on some developments at this plant is given.

Development of Steel Industry in India. R. N. Dutt. (*Iron Steel Rev.*, 1958, **2**, Aug., 217–219). A lecture.

Pig Iron Production and Steel Production. G. Bulle. (*V.D.I.Z.*, 1958, **100**, Oct. 21, 1463–1469). Some 50 references are given to literature published in 1957 and 1958 on pig iron production, fuel utilization, blast furnace operation, direct iron processes, steel production, O.H. steelmaking, arc furnace steelmaking, converter processes, and improvements in casting techniques.—L. J. L.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

The Changing World of the Extraction Metallurgist. F. D. Richardson. (*Imperial College, London, Inaugural Lecture*, 18 Feb., 1958; pp. 124). A section on the blast furnace is included (111–115).

Comparisons of Operational Economy in the Iron and Steel Industries. G. Winkler. (*Neue Hütte*, 1958, **3**, Sept., 543–548). The concept of "economy" is defined; the methods of investigating the economy of metallurgical processes are described and illustrated by two examples: a comparison between a rotary and a low-shaft furnace, and the determination of the most economical method of producing pig iron.—L. J. L.

Pig Iron. A. S. Bam. (*Iron Steel Rev.*, 1958, **1**, Feb., 49–51). The production of pig iron in India is briefly described and the future prospects and demand are considered.

The Inauguration of No. 5 Blast Furnace "d'Usinor" at the Denain Works. (*Usine Nouv.*, 1958, **14**, Sept. 18, 13–14). A description of the furnace is included.

The Royal Netherlands Blast Furnaces and Steelworks and Affiliated Companies. (*Metallen*, 1958, **13**, May 20, 40–45). [In English]. An account of the history and development of Koninklijke Nederlandsche Hoogovens en Staalfabrieken at Ijmuiden, and its associated companies Breedband N.V. (wide strip mill) N.V. Mekog (chemical products) and CEMIJ N.V. (cement from blast furnace slag).

The Rapid Development of the Iron and Steel Industry in the Years of Popular Government. D. A. Stanescu. (*Met. Constr. Masini*, 1958, (6), 472–486). [In Rumanian]. This article deals mainly with blast-furnace production of pig iron, and with the great improvements in their construction and methods of operation.—L. E.

Velocity of Iron Oxide Reduction with Charcoal. Lu Chao-Chi, Shen Pong-Ju, King Da-Kong and Wu Tzu-Liang (*Acta Met. Sin.*, 1958, **3**, (2), 111–119). Mill scale reduced with charcoal yields a high-grade iron powder (more than 98·5%Fe). At about 1000°, the ferric and ferroso-ferric oxides are completely transformed into ferrous oxide within a few minutes prior to the formation of metallic iron, but the reduction of ferrous oxide to metal takes a much longer time. The activation energy for the growth of the iron substrate on the wüstite surface was found to be 57 000 cal/mole being comparable with the activation energy of CO formation in solid reducing agents such as coke. The reduction rate of wüstite is also conditioned by the temperature of CO formation from charcoal.

Reduction of Metallic Oxides with CO. J. Weber. (*Koh. Lapok*, 1958, **13**, Feb.-March, 122–130). The reducibility of metal oxides with CO and the equilibrium relations of the reducing processes are investigated on the basis of thermodynamic data.

Reduction of Iron Oxide in a Bed with High Gas Pressure. A. S. Tumarev and L. A. Panyushin. (*'Stal'*, 1958, (9), 769–776). Increased pressure accelerated reduction and in general the more difficult the oxide is to reduce the greater is the effect of pressure. This must occur in the blast-furnace under pressure, and reduction in the low and medium temperature regions must be raised.

A Comprehensive Survey of Hungarian Pig Iron Production: Its Economy and Future. P. Pilter. (*Koh. Lapok*, 1958, **13**, May-June, 217–226). The author discusses the raw materials (iron and manganese ores, red mud, pyrites cinder, flue dust, steel scrap, coke) and the technique of pig iron production in Hungary.—P. E.

Correlation between Theory and Experiments on, the Reduction of Iron Ore. G. Heynert, E. Schürmann and J. Willems. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1493–1505). The various reactions involved in the reduction of iron ore are discussed and the individual reactions of the various components described with the aid of equilibrium diagrams. The reaction rates of iron oxides with CO and CO_2 are greatly increased if solid solutions or compounds of other oxides are present and if these oxides are either pasty or liquid. Experiments for the study of the individual reactions involved in the reduction of iron ore are described and their significance to blast-furnace practice pointed out.—T. G.

Dephosphorisation of Alloys in Hydrogen, II. B. Chatterjee and S. R. Bhattacharjee. (*Trans. Indian Inst. Met.*, 1958, **11**, Sept., 37–39). Five cast irons with 0·76, 0·5, 1·1, 1·3 and 0·9%P were examined ground to 40 mesh and heated to 1000° C in a current of H_2 containing 1·2% moisture. Drillings from a 2·04%P–Fe alloy were also used. The latter did not appear to lose P, but samples III and IV lost ~ 30%, samples I, II and V not being affected. Further work is in progress.

Some Problems of Hygiene in the Work Connected with Burdening Modern Blast Furnaces. B. A. Katsnel'son. (*Stal'* 1958 *supplement* "*Blast Furnace Production*," *Metallurgizdat*, 1958, 143–152). The problems connected with health safeguards for workers are reviewed. These mainly include measures against dust, such as ventilation systems and air purification, moistening and precipitation of dust as it arises, the provision of forced air changes and individual protection of the respiratory organs.—L. H.

The Ventilation of Hot Blast Stove Houses. P. V. Sidyakov, M. Ya. Zarzhevskii and G. F. Ermolaeva. (*Stal'*, 1958, (8), 691–693). The installation of air vents and the provision of wind screens is described. The temperature difference between the exhaust air and the outside atmosphere should be kept at 10°.

Pig Iron as a Raw Material. S. V. B. l'Abbate. (*Bol. A.B.M.*, 1958, **14**, July., 275–316). [In Portuguese]. The main theme of this discussion is provided by S. V. B. l'Abbate whose paper has the above title. This is given in pp. 284–300. Methods of making pig iron are reviewed briefly, quality is discussed and specifications are given. Figures and tables are given to illustrate the increasing consumption of pig iron and the growth of the Brazilian iron and steel industry. Two short papers, **Pig Iron for Malleable Cast Iron.** T. Kitice, (278–280), and **Refined Pig Iron of the "Prometal" Type.** G. B. Cox (280–281) are also included. The former discusses the requirements of and markets for this type of pig iron while the latter describes the MBC process being set up at Cumbica.—P. S.

The Quality of Blast Furnace Pig Iron. L. I. Gol'denberg. (*Stal'*, 1958, (10), 874–877). Using ore and sinter, or sideritic ores there is very little contamination with graphite. When cast in rapid cooling light-weight pigs graphite is transferred from the core to the surface and the cupola gases then remove it practically completely.—R. S.

Transport of Molten Pig Iron. W. Jurisch. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1606–1608). A review of the transport of molten pig iron by railways on main lines, public roads and waterways is given with particular emphasis on vehicle design and safety precautions during transport. Transport by railway has proved to be very satisfactory, transport on public roads is not recommended.—T. G.

A Contribution to Low-Shaft Furnace Metallurgy. K.-F. Lüdemann. (*Neue Hütte*, 1958, **3**, Sept., 523–533). A description of the design and operation of the furnaces at Calbe is followed by a report of experimental results on reduction processes in the low-shaft furnace. It was found that there exists a correlation between the Mn and Si reductions, and between Si reduction and desulphurization.—L. J. L.

The Future of the Argentine Iron and Steel Industry and the Trials with the Experimental Low Shaft Furnace of OEEC. A. Cresta. (*Tecn. Indust.*, 1958, **36**, July, 789–793). [In Spanish]. The author points out that although the Argentine has good ore deposits available in the Sierra Grande (estimated reserves of 1000 million t) the coal in the country's major source at Rio Turbio (estimated reserves of 400 million t) is not suitable for making metallurgical coke. Coal production will reach 2 million t/annum in 1965 and at that time the Zapla and San Nicolas blast furnaces will be producing 1½ million t/annum of pig iron. Both cost and development are affected by the need to import suitable coals and unless new types of furnaces are used the situation will worsen. The author describes the Ougrée plant and the results of the trials to emphasize the belief that this approach could resolve future difficulties.

Production of Pig-Iron in the Low-Shaft Furnace. G. von Struve and R. Ebert. (*Iron Coal Trades Rev.*, 1958, **177**, Oct. 17, 911–917; from "*Bergakademie*" (*Freiburg*), April, 1958). The plant at Calbe in E. Germany is dealt with, giving furnace construction and details of operation. The works has 10 units and produces 250 000 metric t/year. Other types of low-shaft furnace are described. Conditions of reduction, desulphurization, Mn recovery and possible O_2 enrichment are set out. (19 refs.).

Studies on the Efficiency of the Low Shaft Furnaces at the VEB Iron Works West at Calbe and Attempts to Increase Production by Increasing the Volume of Blast. K. Säuberlich and H.-J. Lux. (*Neue Hütte*, 1958, **3**, May, 294–300). The 10 low-shaft furnaces at Calbe differ in size and in number of tuyères. The smaller furnaces were found to be more efficient. The volume of blast in the larger units was found to be inadequate. When the blast volume was increased, production went up by 23%.—L. J. L.

Oxygenation of Grey Cast Iron. A. Arasti Abaunza. (*Inst. Hierro Acero*, 1958, **11**, Apr.-June, 91–96). [In Spanish]. Experiments to control the Si content in the ladle by means of oxygen injection through a water-cooled tube are described. 50 kg. Samples were treated for various times and then cast into test bars. The results indicate that 25–30 l of oxygen per kg iron are needed to reduce the Si by about 40%; a pressure of 7 atmos is recommended.—P. S.

Pneumatic Drive for Rotating a Mixer and Relieving Stresses. V. S. Brazhnik. (*Metallurg*, 1958, (9), 19–20). A pneumatic drive for rotating a 1300-t mixer at Krivoi Rog is described.—R. S.

Desulphurising Pig Iron Outside the Blast Furnace. J. Dévényi. (*Koh. Lapok*, 1958, **13**, May-June, 262–268). The following methods of desulphurizing are discussed: 1. Precipitation of MnS by decreasing the temperature. 2. Treatment of molten pig iron with liquid or solid reagents. The latter method is carried out either in a rotary drum furnace, or by blowing a carrier gas that contains the solid reagents into the molten pig iron. Hungarian experiments are described in which desulphurization was performed by blowing nitrogen gas and powdered quick-lime into the molten pig iron.—P. K.

Preparation of Iron from the Fused Eutectic Mixture of KCl–LiCl + $FeCl_2.4H_2O$. S. Zulkiewicz. (*Compt. Rend.*, 1958, **247**, Nov. 10, 1604–1608). Electrolysis is described giving iron 99·997% pure.

Sand Dressing on the Pig Bed. W. Riege. (*Giesserei*, 1958, **45**, Sept. 11, 587–589). Ways of rationalizing sand transport in the moulding shop are discussed. Various conveyor systems are suitable for the purpose; the use of tractors and fork lift trucks is advocated.—L. J. L.

Some Investigations on the Treatment of Molten Iron. W. B. Chater and J. A. Charles. (*JISI*, 1959, **191**, Apr., 319–328). [This Issue].

The Practical Aspects of Pretreatment Processes. J. L. Harrison. (*JISI*, 1959, **191**, Apr., 328–336). [This Issue].

PROPERTIES, TREATMENT, AND USE OF SLAGS

Slag-Iron Blast-Furnace. W. W. Key. (*U.S. Bur. Mines, Min. Yearbook*, 1956, **1**, 1057–1066). Statistical, with notes on technology and uses.

Crystallisation Isotherms of Blast-Furnace Slags of Different Compositions. C. Brisi and A. Uslinari. (*Silicates Ind.*, 1958, **22**, Oct., 502–507). The authors describe studies of the devitrification isotherms of two industrial and one synthetic slag. The phenomena were found to be governed by a process of nucleation and growth. The rate of crystallization is temperature-dependent

Structural and Thermodynamical Basis of the Reactions of Liquid Metallurgical Slags. T. T. Negrescu. (*Acad. Romine Met.*, 1958, **3**, (2), 161–202). [In Rumanian]. Investigations into the constitution of liquid metallurgical slags have established quantitative relations regarding the ion groupings which form in the molten mass of silicates, and a general outline of the configuration and mechanism of some of these groupings of which some are chemically active whilst others remain neutral. Structural considerations not previously taken into account have helped to clear up some problems and to revise some ideas generally held regarding dilute and concentrated solutions. Similarly the concept of grouping has helped to clarify the idea of thermodynamical activity and justified the notion of an activity coefficient, although its shortcomings are seen in its unexplained variation as a function of the chemical composition. The author suggests a constant value which has to be subtracted from the analytical concentration in order to obtain the numerical value of thermodynamical activity.—L. H.

Decomposition of Hard Soluble Foundry and Open-Hearth Slags by the Sintering Method. Yu. I. Usatenko and N. P. Fedash. (*Zavods. Lab.* 1958, (10), 1180–1181). It has been found experimentally that sintered substances dissolve in acids much more rapidly than fused substances. Slags with a greater content of silica and aluminium oxide prove more resistant to decomposition by sintering and dissolution in acids; the presence of manganese and chromium speeds up the process. Usually 0·15 g of finely ground slag is sintered with 0·1 g of Na_2CO_3. Sintering takes 10–15 min. at 1000–1100° C for more stable specimens, and 5–10 min., at 900–1000° C for those containing some Mn and Cr. Chemical composition and results of tests of various slags are tabulated.—S. S.

Determination of Phase Composition in Silicon Alloy Slags. M. V. Babaev and N. M. Kostyanovskaya. (*Zavodsk. Lab.*, 1958, (10), 1183–1184). Ordinary chemical analysis of the Si content in slags does not give the percentages of different silicon compounds in the specimen. This knowledge is necessary for the correct carrying out of the melting process. The article describes three chemical methods devised and used in the Chelyabinsk Iron Works for determination of silicon carbide, free silicon and of silicon monoxide.—S. S.

DIRECT PROCESSES

Recent Developments in Iron Smelting and Steelmaking Processes. W. M. Armstrong. (*Can. Min. Met. Bull.*, 1958, **51**, Sept., 574–576). Factors in the demand for an alternative to conventional processes are noted and the current methods of direct reduction are briefly noted.

New Process Yields Quality Pig. A. de Sy. (*Iron Age*, 1958, **182**, Sept. 18, 92–94). A direct reduction process for iron ore is described which uses carbon for reduction and electricity as the energy source. The process is for 65% iron feed and yields high grade pig iron or carbon tool steel.—A. G.

PRODUCTION OF STEEL

The Kinetics of Steel Manufacture. L. von Bogdandy, W. Dick and I. N. Stranski. (*Arch. Eisenh.*, 1958, **29**, June, 329–337). With reference to the literature and to experiments described by the authors, the kinetics of decarburization and dephosphorization are discussed in relation to the Thomas, O.H. and Rotor processes. Possibilities of reducing the amount of brown fumes released into the atmosphere as a result of oxygen refining are also discussed. (55 refs.)

Economic Comparison of Different Types of Steel Manufacturing Processes with Special Regard to the Development of Iron and Steelmaking Techniques in Eastern Germany. K.-F. Lüdemann. (**Neue Hütte*, 1958, **3**, Aug., 462–474). In view of the fact that the present steel capacity in Eastern Germany is approaching saturation with an annual production of 3 million tons, a survey is made of existing steelmaking processes, with reference to conditions in Eastern Germany, as they exist now or are likely to develop in the future. The object of the study is to facilitate future development.

Oxygen and the Steel Plant. J. H. Strassburger, N. R. Kirkdoffer, R. A. Lambert, G. T. Wright and C. J. Schilling. (*Iron Steel Eng.*, 1958, **35**, May, 69–94). This article is a compilation of papers on oxygen usage presented by the authors at the 1957 Annual convention of the A.I.S.E. in Pittsburgh. The papers deal with operating results, the benefits of purchased oxygen to Inland Steel, the economics of generated versus purchased oxygen, the operation and maintenance of a 100-t double-cycle gaseous oxygen plant and maintenance experience with oxygen plants at Sparrows Point. The question of dimensioning an oxygen plant for a steelworks is also discussed.—M. D. J. B.

A System of Collecting Alloy Steel Scrap. E. Weigl. (*Koh. Lapok*, 1958, **13**, Jan. 24–27). The author describes an adequate system for collecting and handling alloy steel scrap in Hungary.—P. K.

Trade Organization for Scrap in France and in the C.E.C.A. (*Aciers Fins Spéc.*, 1958, July, 4–8). The history of French organizations for the control of scrap prior to 1952 is outlined, followed by a description of the organization on the opening of the Common Market in that year.

Steelmaking Problems in the Poldi Plant. A. Danihelka. (*Hutnik*, 1958, **8**, (6), 187–189). An account is given of steel-making technology in the Poldi Works, with particular reference to those features to which the fame of Poldi steels is thought to be primarily due.

Some Important Factors in Heating. D. Dioszeghy. (*Koh. Lapok*, 1958, **13**, Feb.-March, 80–85). The most important factors in heating, such as combustion and heat transfer, furnace construction and atmosphere, steel quality and surface characteristics are discussed. Theoretical and empirical formulae are given for calculation of the heating time.—P. K.

Bessemer Steelmaking. (*Swedish Foreign Commerce*, 1958, (5), 33–36, 54). An account of the Edsken centenary and a note on the Kaldo process are given.

Study of the Thermal and Physico-Chemical Evolution of the Thomas Conversion by Recording the Bath Temperature. J. Galey, L. Beaujard, P. Vallet and G. Urbain. (*IRSID Communication aux Journees d' Automne*, 1958, Sept., pp. 10). The equipment used for the optical measurement of the bath temperature during the blowing of a basic Bessemer heat is described and the results obtained are discussed in relation to the reactions taking place.

The Behaviour of Chromium in the Basic Bessemer Converter. P. Goldstein and E. Eickworth. (*Stahl Eisen*, 1958, **78**, Sept. 4, 1235–1246). Iron containing up to 1·85%Cr was blown without limestone addition, but Si was added to some of the charges. The Cr content was reduced to less than 1% Cr behaves in the converter similarly to Mn, but since it is slightly nobler, the Cr level in the finished steel is higher than that of Mn. High reaction rate stimulated by rapid temperature increase promotes the removal of Cr. The elimination of Cr requires great quantities of slag. The trials and the results obtained are described in detail and fully discussed.—T. G.

Use of Green Converter Bottoms in the Basic Bessemer Converter Plant Seraing of the S.A. Cockerill-Ougrée. R. Schuermans and J. Van Neste. (**Stahl Eisen*, 1958, **78**, Sept. 18, 1308–1313; *Rev. Univ. Mines*, 1958, **101**, Aug., 270–279). Green bottoms—after ageing for some weeks—were mounted in the converter and fired by a fuel-oil flame. The production of the bottoms is described in detail. For acceleration of the polymerization process 2%MnO_2 is added to the dolomite mixture. Porosity of the bottoms was reduced from 12–20% for fired bottoms to 6–8% for green bottoms. High residual carbon content of the green bottoms contributes much to their long life.—T. G.

Recording the Temperature in the Bath by Sighting into the Nose of the Convertor. J. Galey. (*Centres Doc. Sidér. Circ.*, 1958, **15**, (5), 1049–1058). A description is given of a method of measuring the temperature of the metal in a convertor by viewing the metal from above through the nose of the convertor. A monochromatic optical pyrometer is used. The results obtained are discussed and show how the method can follow the changes in bath temperature, which occur during blowing.—B. G. B.

Method for Vibrating Converter Bottoms. E. Glaesener. (**Stahl Eisen*, 1958, **78**, Aug. 21, 1169–1175). The author reports on the development of various methods and devices for vibrating converter bottoms. Dolomite consumption fell by 20% when using bottoms that were vibrated, the main advantage is, however, their very much longer life, up to 100 heats. (*Rev. Univ. Min.*, 1958, **101**, Aug., 261–269). A method is described of vibrating bottoms for 30-t converters, using a plate fitted with three vibrators and 13·5 mm spindles. Various modifications are described and the results compared. A substantial increase in the average life of the bottom was obtained.

Application of the L.D. Process to the Treatment of Phosphoric Irons. Lambert and Messin. (*Centre Doc. Sidér. Circ.*, 1958, (4), 819–833). A description of the L.-D. plant at the Pompey works in France is given. One of the four 18-t basic Bessemer convertors has been adapted. A comprehensive review of the results obtained during the development of the process at Pompey is presented. Irons containing up to 1%P have been treated successfully. The process involves three separate blows and two deslagging operations and it is not necessary to reach low carbon levels to obtain phosphorous removal. Details are given of the mechanical properties of the steel produced and of the costs.—B. G. B.

Tar Bonds Oxygen Vessel Bricks. J. P. Holt. (*Steel*, 1958, **143**, July 7, 74–78). Tar bonded basic refractories are particularly suitable for use in oxygen-blown converters, and types of bricks and their use are described. The bricks contain magnesia, dolomite or mixtures, usually a large and a small size fraction mixed with 4 to 7% tar. Special care may be necessary to prevent hydration of the bricks during storage, and damage to the lining during warming up.—D. L. C. P.

Desulphurisation of Basic Converter Steel by Top Blowing. S. I. Lifshits. (*Stal'*, 1958, (9), 788–793). To produce steel with not more than 0·04%S the pig iron must contain not more than 0·05%S. Where this is higher longer heating, greater iron losses and the use of more Fe–Mn occur. The use of soda in the ladle is satisfactory if the slag does not get into the mixer and so into the converter. In top blowing, the Mn in the iron and the Mn_3O_4 in the slag are important and the part played by slag basicity is small because of the rapidity of the process.

Injection of Pulverised Materials into the Converter Blast. B. Trentini, P. Vayssiere, R. Alleyrac and J. Legrandjacques. (*IRSID, Communication aux Journées d'Automne*, 1958, Sept., pp. 25). Trials injecting various amounts of powdered lime and Thomas slag into the blast of an air-blown basic Bessemer converter were carried out, and the effect of injecting pulverized ores of various types as cooling agents. The lime additions could be used to shorten the blowing time by reducing ejection losses when the blast rate was increased; the amount of lime required increased with the initial silicon content of the iron. More Thomas slag was needed to obtain comparable results, but its use provides a means of disposing of low-grade slag. The increase of nitrogen in the steel with this treatment was investigated.

Refining of Pig Iron with Pure Oxygen and Lime Powder. The O.L.P. IRSID Process. B. Trentini and M. Allard. (*IRSID, Communication aux Journées d' Automne*, 1958, Sept., pp. 18). Results of industrial-scale trials of this process in 30-t converters are reported and discussed. Very low contents of P, S and N are obtained, and the steel produced is comparable in quality with the best O.H. steels.

Study of New Methods of Construction of Separation Walls. M. Poulain. (*Centre Doc. Sidér. Circ.*, 1958, **15**, (5), 1073–1077). The construction of the dividing wall between gas and air uptakes in O.H. furnaces is discussed. Two types are described—one of solid brick and the other incorporating a hollow air gap.—B. G. B.

An Analysis of Repair Costs and Output Figures of Basic Open-Hearth Furnaces with Siliceous and Chrome-Magnesite Roofs in the Polish Iron and Steel Industry. W. Hansel. (*Hutnik*, 1958, **25**, April-May, 142–156). This wide review of costs and output figures shows that in every instance the repair costs of furnaces with chrome-magnesite roofs were higher than those of furnaces with siliceous roofs. Only in certain instances is there possible justification, on purely metallurgical grounds, for the retention of chrome-magnesite roofs in furnaces, in view of their high repair costs.—M. T.

Valuation of Various Fuels for Use in the Open-Hearth Furnace. U. Plöger. (*Stahl Eisen*, 1958, **78**, July 24, 1067–1971). The tendency to use more and more fuel oil affects the consumption of blast-furnace and coke-oven gas considerably. The O.H. furnace is an ideal consumer of these gases. The author reviews the thermal efficiency of various gases and their mixtures for use in the O.H. furnace and reports on the published results of a number of theoretical and practical investigations.—T. G.

The Use of Oxygen in a Modified Tilting Furnace. A. Jackson. (*JISI*, 1959, **191**, Apr., 337–342). [This Issue].

Novel Oil-Heating Equipment for Open-Hearth Furnaces. W. Schleicher and K. Boleg. (**Stahl Eisen*, 1958, **78**, Aug. 7, 1108–1109). A novel oil-firing equipment for O.H. furnaces of 130–350 t capacity is described. The oil is heated by hot, compressed blast-furnace gas, compressed blast-furnace gas forces the oil into the burner and heated gas atomizes it. The use of blast-furnace gas and oil alone apart from a compressor for the gas renders the equipment very simple and reliable.—T. G.

Cell-Type Refractory Bricks and Their Use in the Roofs of Open-Hearth Furnaces. F. Hönig-Hönigsberg. (*Stahl Eisen*, 1958, **78**, Sept. 4, 1262–1264). A review of published information on the advantages of cell-type refractory bricks for roofs of O.H. furnaces particularly of the suspended-arch type.—T. G.

Rate of Desulphurization of Molten Iron by Slag under Reducing Conditions. II. Influence of Silicon and Manganese. Y. Kawai. (*Nippon Kinzoku*, 1956, **20**, May, 277–281). At 1490–1560° C the rate of sulphur-transfer from metal to slag increases with increasing Si and Mn content in the metal, but the rate in the other direction does not appreciably alter. The mechanism is discussed.—K. E. J.

The Use of Oxygen in Duplex and Stationary Open-Hearth Practice. O. Pearson. (*JISI*, 1959, **191**, Apr., 305–318). [This Issue].

Practical Realisation of the Desulphurisation of Pig Iron by Injection of Powdered Lime According to the IRSID Process. B. Trentini, J. Raguin and M. Dannewald. (*IRSID, Communication aux Journées d' Automne*, 1958, Sept., pp. 40). Molten iron is desulphurized by transferring it from a hot-metal mixer to a specially-designed, converter-like ladle, by means of several tuyeres immersed in the bath. The results of this treatment, combined with reducing additions such as Al or Mg to the ladle are examined, and economic factors are considered. Industrial trials in 12-t converters were successfully carried out.

The Prevention of "Lighting Off" Explosions. J. B. Smith. (*Iron Steel Eng.*, 1958, **35**, May, 144–148). A gas safety control system is described, which was developed by an insurance company against one of the primary causes of explosions: the premature admission of gas to open burner cocks.

Recent Trends in Open Hearth Refractory Practice, with Special Reference to All-Basic Practice. J. McCracken. (*Indian Construction News*, 1958, Feb., 74–76). The improvements in the design and quality of basic O.H. roof refractories are discussed.

Steelworks III of Hoesch-Westfalenhütte A.G.-Dortmund. E. Wiegand. (*Demag Nachrichten*, 1958, (151), 1–7). The post-war construction and operation of this O.H. steelworks are described in detail.

Steel Making Practice in Bochumer Verein A. G. Bochum. S. Prasad and S. S. Taluja. (*Iron Steel Rev.*, 1958, **1**, Feb., 83–86). Basic open-hearth practice at Bochumer Verein is described.—B. C. W.

Increasing Open Hearth Productivity at Magnitogorsk. A. G. Trifonov. (*Metallurg*, 1958, **7**, 18–19). Among measures taken to increase productivity are: mechanization of feed of deoxidizers; mechanization of tap hole opening; double-stopper pouring and mechanized tundish pouring; improved fettling machines with complete elimination of hand fettling. A seven-hour working day has been achieved without increasing the labour force.

The Use of Pig Iron with Low Manganese Content in Open Hearth Furnaces. G. Répási. (*Koh. Lapok*, 1958, **13**, May-June, 251–261). After reviewing Russian experience on the use of 0·5–1% Mn pig iron in O.H. practice, the author discusses Hungarian experiments with 1%Mn pig iron. Efficiency is improved by using an adequate content of Si (0·8–1%), and by desulphurizing the pig iron outside the blast furnace.—P. K.

Experience Gained in the Production and Working of Continuous Cast Bars of Small Cross-Section. F. Leitner and F. Schmidt. (*Stahl Eisen*, 1958, **78**, July 24, 1028–1032). Experience gained in the last four years in the casting of bars for wire-drawing and slabs for thin sheet is reported with special emphasis on defects observed and remedies for eliminating them. High casting velocity of small sections (about 4½ in. in diameter) led to separation of the castings, this was overcome by oscillating the mould. The use of protective atmospheres to prevent oxidation of the molten metal in the pool is mentioned. The hot-working properties of the continuous cast bars are discussed.—T. G.

Continuous Casting of Squares at Novo Tula. V. S. Rutes and N. A. Nikolaev. (*Metallurg*, 1958, (10), 15–18). This machine produced 35 t/h of slabs but only 15 t/h of 6 in. squares. This article contains some new Russian photographs of continuous casting. Some new operational data not previously published are also given. Some information is presented on the relationship between casting speed and depth of pipe.—R. S.

The Effect of Aluminium in Deoxidation on the Separation of the Deoxidation Products. R. Rosegger. (*Radex Rundschau*, 1958, Sept., 292–305). Results are reported of a series of tests on the reaction processes occurring in deoxidation with Si alone, with Si and a maximum of 0·4 Kg Al per t of steel, with Si and Al in equal parts, and with Al alone. It was found that the rate of separation of particles in the steel bath is determined by surface tension and the wettability of the reaction products by liquid steel.—L. J. L.

The Effect of Preventing Pipe on the Yield and the Quality of Steel Ingots. G. Csabalik. (*Koh. Lapok*, 1958, **13**, Jan., 20–23). Various methods for preventing pipe in steel ingots are reported. For heating of the hot top it is recommended to use O_2 in killed mild steel ingots, and thermite in higher C and alloy steel ingots. The author claims an increase in yield of 6–8% without loss of quality of steel, by using these methods.—P. K.

Experiments with Exothermic Hot Top Sleeves. G. Csabalik. (*Koh. Lapok*, 1958, **13**, Feb.-March, 118–122). Hungarian experiments with thermite sleeves in hot top of 320–360 kg ingots have resulted in a 8–9% increase in yield. The method is especially economical for high alloy steels, e.g. high speed steels.—P. K.

The Causes of Blow Hole Formation in Some Types of Killed Steels. J. Chvojka. (*Hutnik*, 1958, **8**, (6), 199–203). Causes of the occurrence of small blow holes in killed steels are enumerated, and methods of prevention are discussed.—P. F.

PRODUCTION OF FERRO-ALLOYS

The United States Ferro-Alloy Industry in 1955 and 1956. (*J. Four Elect.*, 1958, **63**, (4), 125–127). Data are given of production and consumption of the principal ferro-alloys in U.S.A., and of imports and exports of these materials for the years 1955–56.

Ferro-Alloys. P. H. Royster and H. V. Heidrich. (*U.S. Bur. Mines Min. Yearbook*, 1956, **1**, 475–492). Mainly statistical but with notes on uses.

Ferro-Manganese Production in the Blast Furnace. I. Kókai. (*Koh. Lapok*, 1958, **13**, May-June, 290–293). Hungarian experiments on Fe–Mn production in a blast furnace using increased blast are described. In the discussion Russian practice in large blast furnaces is reviewed.—P. K.

FOUNDRY PRACTICE

Progress in Iron Castings. H. Bornstein. (*Trans. A.F.S.*, 1957, **65**, 1–16). A lecture. The rise in the quality of irons in A.S.T.M. specifications since 1916 and the increased range of grey and white iron castings, the properties of malleable castings and the development of pearlitic malleable and nodular irons are described and many castings are shown. Sections on the cupola and on automation are added.

The Foundry Industry in the Netherlands. (*Metalen*, 1958, **13**, May 20, 31–34). [In English]. A short, illustrated account of the history, development and organization of the Dutch foundry industry.

Present and Future Problems of the Material Economy of our Foundry Industry. A. Bartusch. (*Giessereitechn.*, 1958, **4**, Aug., 177–179). Problems associated with the present increase in foundry production and the fulfilment of plans for the future in the German Democratic Republic are discussed.

The Foundry Potential of India. J. Blakiston. (*Iron Steel Rev.*, 1958, **1**, Feb., 39–42). The development, present position and future prospects of the Indian foundry industry are briefly discussed.—B. C. W.

Iron Founding in India. K. L. Chowdhary. (*Iron Steel Rev.*, 1958, **1**, Feb., 69–70). The history of the iron founding industry in India is very briefly reviewed and its present position and future prospects are considered.—B. C. W.

The Problem of Labour Consumption and Yield of Steel Castings Based on the Example of Zygmunt Ironworks. J. Glogier. (*Prz. Odlew.*, 1958, **8**, Sept., 249–257). [In Polish]. In 1957 the production of steel castings in Poland amounted to 160 000 t, i.e. 16% of all castings; this percentage is higher than in the highly industrialized western countries. In view of still rising requirements of the home market the author suggests, that the rational planning of foundries should be based on two factors: labour consumption, defined as the ratio: manhours/t of casting, and yield-weight of casting/molten steel used. A detailed analysis of these two factors was carried out in Zygmunt Ironworks; castings were classified according to their weight and the complexity of the production process. Results were tabulated. The author regrets that the method of planning suggested has not yet received official approval.

The Specific Effects of Iron and Steel Castings in Machine Construction. F. Naumann. (*Lit. Proizv.*, 1958, (7), 30–32). The article deals with many problems arising in the industry and makes suggestions for improvements both in tools, lay-out and organization.

The Use of Gases in the Foundry and in Metallurgy. A. Portevin. (*Rev. Met.*, 1957, **54**, Nov., 813–816). An outline of the effects of the use of gases at various stages in the manufacture of a casting or ingot is given.

G.E. Foundry Mechanisation.—II. R. H. Herrmann. (*Foundry*, 1958, **86**, May, 158–163). Layout and operation of the medium-casting (30–400 lb) foundry of the General Electric Co., Elmira, N.Y., are described. Moulds are made on cop-and-drag machines and metal is supplied by two continuous-tap, front-slagging cupolas. Casting-cleaning operations are also dealt with. Defective castings are sorted out during the cleaning operation and the nature and amount of scrap from each type of casting are recorded.

Scope For Foundry Mechanisation In India. K. S. S. Vasan. (*Iron Steel Rev.*, 1958, **1**, Feb., 75–79). The possibilities of applying mechanization to Indian foundry practice are discussed.—B. C. W.

Saving Space. J. A. Riley, jun. (*Mod. Castings*, 1958, **34**, July, 24–25). Floor space in the foundry of the Cooper-Bessemer Corp., Ohio was saved by placing the moulds after casting on flat cars, and pulling outside for cooling. Necessary modifications to the equipment are described.

Future Progress in the Melting of Metals. F. Hudson. (*Fond. Belge.*, 1958, **28**, Apr., 154–162). Furnaces, coke and oil fired and electric, and effects of H_2, O_2, N_2 and methods of fusion are reviewed.

Cupola Blowing with Centrifugal Blowers. (*J. d'Inf. Tech. Indus. Fonderie*, 1958, March, 23–25, 27). A review.

Results of Recent Studies on Cupolas. W. Patterson. (*Giesserei*, 1958, **45**, Sept. 11, 525–531). It is shown that the disadvantageous effects of using hot blast can be remedied. Coarse coke of increased density, and supplied with a crust of cement, to which CaC_2 has been added, will have a beneficial effect on combustion.—L. J. L.

Recent Trends in Foundry Refractory Practice. J. F. Schnur. (*Indian Construction News*, 1958, Feb., 93–95; discussion 95). The importance of suitable fireclay quality and good cupola bricklaying and patching technique are emphasized.

Mechanisation in Shell Moulding Practice. L. Kálmán and I. Szilágyi. (*Koh. Lapok*, 1958, Jan., Öntöde 22–33). Various kinds of shell moulding equipment and applicators are described, and suggestions are made for using some of them in Hungarian shell-moulding practice.—P. K.

Waterglass as a Binder for Moulding and Core Sands. F. W. Nield and D. Epstein. (*Giesserei*, 1958, **45**, Sept. 11, 567–575). A study has been made of the hardening process of waterglass-bound moulding sand after gassing with CO_2. The binders used were waterglass with $SiO_2 : NaO_2$ ratios = 2·0; 2·5; 2·9 and 3·3. The characteristics of waterglass are however, determined also by the $SiO_2 + Na_2O$ content which affects specific weight and viscosity, so that a different crushing strength: gassing period curve was obtained for each waterglass.—L. J. L.

Construction of Pattern Equipment for the Shell Moulding Process. W. Birke. (*Giessereitechn.*, 1958, **4**, Aug., 179–187). The various aspects of pattern making and core box construction are discussed from the point of view of the three types of machine available in East Germany. Lines of future development are suggested.

Shell Moulding in a Hungarian Foundry. G. Bánky. (*Koh. Lapok*, Öntöde, 1958, **9**, May-June, 118–122). The author describes the use and technique of shell moulding as applied in a Hungarian foundry.—P. K.

Introduction of Waterglass Bonded Moulding Materials in Foundry Practice. L. Hajdu. (*Koh. Lapok* Öntöde, 1958, **9**, May-June, 110–117). Hungarian experiments with sodium silicate bonded moulding materials are described. The advantages and disadvantages of the method are discussed.—P. K.

The Removal of Moulds of Sodium Silicate Hardened with Carbon Dioxide. Jeancolas and Virolle. (*Usine Nouv.*, 1958, **14**, Oct. 2, 23, 25). A summary of a paper presented at a Conference of the Association technique de la Fonderie in May. Recommendations for design, casting and the use of organic materials (molasses, glucose, wood flour, bone black and graphite) are made.

Sodium Silicates for the CO_2 Process. E. A. Lange and R. E. Morey. (*Mod. Castings*, 1958, **34**, July, 41–49). Investigations of the CO_2–sodium silicate process showed: the strength of sand mixtures increased at a greater rate with higher SiO_2/Na_2O ratios; maximum gassed strength increases with increased SiO_2/H_2O rates of the silicate, and the dry strength of sodium silicate-bonded with sand is related to the composition of the silicate and the CO_2 gassing time.

Flow of Heat from Sand Castings by Conduction, Radiation and Convection. C. M. Adams, jun. and H. F. Taylor. (*Trans. A.F.S.*, 1957, **65**, 170–176). The Chvorinov relation is modified to take into account the effect of mould contour on the solidification of compact castings. Patterns were designed for measurement of mould thermal properties and measurements of heat radiation from metal surfaces (in open risers) were made. Non-ferrous metals were used.

Consideration of Stress and Strain Produced in Ferrous Castings. B. V. Mahabale. (*Iron Steel Rev.*, 1958, **1**, Feb., 87–89). The factors leading to the development of internal stresses in castings are discussed together with methods of avoiding or removing such stresses.

New Foundry Testing Methods. C. A. Koerner. (*Trans. A.F.S.*, 1957, **65**, 181–187). A review of radiography, ultrasonic, electronic and other methods.

Castings from the User's Standpoint. T. Logan. (*Trans. A.F.S.*, 1957, **65**, 97–99). Essentially a table of common defects with notes on inspection.

Heterogeneous Distribution of Oxygen in Cast Iron. G. Blanc and A. Blondel. (*Fonderie*, 1958, Sept., 399–411). After reviewing previous work on this subject, the authors describe a vacuum fusion apparatus and method for the determination of oxygen in iron. Methods of casting and sampling are discussed in relation to the oxygen uptake. (31 references).—R. P.

Hydrogen as it Affects Steel Castings. A. F. Gross. (*Trans. A.F.S.*, 1957, **65**, 365–373). A review. The effects are well known, but practice has lagged behind technical developments and more rigid inspection methods lead to more rejects due to this cause. Defective castings are illustrated and effects on ductility and impact strength are shown. Melting control can eliminate permanent defects, the loss of ductility disappears on natural ageing or can be quickly eliminated by low-temperature heat treatment. Hydrogen embrittlement does not make steels notch-sensitive and flaking is rarely encountered.

On the Formation of Pipes in Cast Irons. L. Sofroni and R. P. Todorov. (*Acad. Romine Met.*, 1958, **3**, (2), 131–149.) [In Rumanian]. The nature of volume changes during solidification of cast iron pieces, under the usual conditions of cooling, depends on the degree of graphitization, which can occur in the stable or unstable phase as a function of the chemical composition, magnesium content and rate of cooling. In the case of nodular graphite irons, which are mostly used, it is necessary, in order to reduce the volume of pipes and surface contraction, to vary the content of eutectic graphite by a corresponding change in the content of carbon and silicon.—L. H.

Hydraulic Removal of Spent Moulding Mixtures. A. A. Dudnik. (*Lit. Proizv.*, 1958, (7), 13–16). A lay-out is described for the installation of a plant for the removal of spent moulding mixtures by means of water. In addition to ensuring most hygienic conditions for the operatives it saves half the cost of removal by conventional methods. The figures are based on a 3 year test at the Gor'ki automatic plant.—L. H.

A Method of Removing Skin and Traces of Moulding Sand. R. Kuhn. (*Giesserei*, 1958, **45**, Oct., 670–671). A description is given of the Kolene-E-Saltbath process, in which an electric current is applied to the casting to be cleaned in a fused salt bath at 450° C.—L. J. L.

Some Information on the Export of Foundry Machinery. (*Prz. Techn.*, 1958, (8) 334–336). [In English]. Polish foundry equipment available for export is described.

New Techniques for Finding "Come and Go" Causes that Affect Quality. E. C. Zuppann. (*Trans. A.F.S.*, 1957, **65**, 88–93). As it is not possible, in practice, to vary only one property at a time a ranking system is described from which significant data can be obtained. It is particularly adapted to items having high defect and scrap rates.

Work Sampling Technique. S. Thaver. (*Iron Steel Rev.*, 1958, **1**, Feb., 105–114). The principles of work sampling are explained and its application to the utilization of a battery of moulding machines is explained.

Laboratory—An Aid to Modern Foundries. K. Srinivasan. (*Iron Steel Rev.*, 1958, **1**, Feb., 103–104). The need for a quality control laboratory in a foundry is emphasized.

Air Pollution and Dust Suppression in a Foundry. A. Riggi. (*Giesserei*, 1958, **45**, Sept. 11, 575–582). A detailed description is given of the dust extraction plant at the Fiat Works in Turin. Measurement of air pollution at the Fiat works is also described.—L. J. L.

VACUUM METALLURGY

New Vacuum Furnace: Versatile Low-Cost Unit. (*Iron Steel*, 1958, **31**, July, 350). A new low-cost vacuum furnace (1275) having a capacity of about 20 lb and working in a vacuum of about 3 mm is used for investment casting and the Shaw process. At working pressure the arc is fairly easy to control and does not scatter unduly. Melting time is 0·8 lb/min and superheating is 0·4 min./lb/100° C. The furnace may be operated as a normal vacuum furnace, as an inert-gas furnace (below 4 lb/in²), as a degassing unit or as a combination of these.—T. G.

Vacuum Treatment of Alloy Steel. G. A. Sokolov, G. N. Oiks and I. I. Ansheles. (*Metallurg*, 1958, (10), 10–14). The Krasny Oktyabr' plant at Stalingrad uses a vacuum of 15 to 20 mm in a 25 m³ chamber for 2–3 min for vacuum treating 12-t heats in 20-t ladles. Details are given of operational conditions, gas analysis and of the processes taking place during vacuum treatment. The casting of steel into a vacuum by top-pouring by a new method without using a vacuum chamber directly in the ingot mould is described.—R. S.

Equipment Used for Vacuum Melting and Casting in the Iron and Steel Industry. A. S. D. Barrett and M. E. Harper. (*JISI*, 1959, **191**, Apr., 366–374). [This Issue].

Producing Transformer Steel Under Vacuum. I. S. Pryanishnikov. (*Metallurg*, 1958, (9), 16–17). Two methods of producing transformer steel were developed on the basis of research with a 150-kg vacuum furnace. It was found that the vacuum induction furnaces used for producing transformer steel should not be of less than 1-t. capacity with a vacuum of about 1 mm mercury column. The charge must be low in S and P. Fe–Si is added under vacuum and the metal is poured either under vacuum or in a neutral atmosphere.—R. S.

The Effects of Vacuum Melting on the Gas Content of Metals. I. Pfeiffer. (*Z. Metallkunde*, 1958, **49**, Sept., 455–460). The O, N and H contents of various iron and nickel melts have been studied. Information on the causes of the reduced gas contents of vacuum melts was obtained from comparative tests on starting materials and on iron and nickel charges subjected to open and vacuum melting respectively.—L. J. L.

The Technology of Steelmaking for Transformers in the U.S.S.R. G. M. Borodulin. (*Hutnik*, 1957, **24**, July-Aug., 272–277). [In Polish]. Chemical compositions and various stages of transformer steelmaking in the U.S.S.R. are described. Special attention is given to the vacuum treatment of the molten steel. Steel thus obtained contained 0·02%C and less than 0·005%S. By applying vacuum treatment to the highest grade transformer sheet steel the amount passing the grade test increased from 49 to 93–94%.

Vacuum Melting: Influence of Hydrogen Pretreatment of Crucibles on Oxygen Content of Iron Charges. T. J. Bosworth. (*Trans. Met. AIME*, 1958, **212**, Aug., 489–493). Hydrogen pretreatment of commercial high-purity MgO and ZrO_2 crucibles showed a substantial reduction of O_2 in iron charges melted in a vacuum in the crucibles. It appears that the major source of reducible O_2 to the Fe charge is the suboxides and impurity oxides rather than the major oxide of the crucible.

Vacuum Melting Today. (*Metal Progress*, 1958, **74**, Aug., 94–99). This report surveys modern methods and products of vacuum melting and considers future trends. A table lists most U.S. alloys in this field and gives compositions and uses. The demand is growing as more high duty parts are required and maximum sizes of ingots are increasing.—D. L. C. P.

Brazing in a Vacuum. F. Bernhard and H. Bumm. (*Vakuum-Techn.*, 1958, **7**, Oct., 153–158). The advantages of brazing in a vacuum are listed. Installations for inductive heating of large components are uneconomical. A description is given of the construction of, and operating experience with, a simple vacuum and brazing installation operating at 10^{-1} to 10^{-2} mm and consisting of a water-cooled vacuum vessel with a heating coil, a rotary vacuum pump, a few valves, and electrical accessories.—L. J. L.

Iron–Chromium–Aluminium Alloys. J. E. Srawley. (*NRL Report* 5124; *P.B.* 131676–050; 1958, Apr. 18, pp. 17). Alloys produced by vacuum melting and forged, containing up to 25%Cr and 11%Al were examined for tensile properties and resistance to corrosion by fuel oil residue combustion products. Alloys with 5%Al and 25%Cr were superior to 310 stainless for boiler tube supports. Dissolved O_2 is kept negligible by the Al, but control of C and N_2 need further study.

RE-HEATING FURNACES AND SOAKING PITS

Heating for Forging. F. Smith. (*Met. Treatment*, 1958, **25**, Nov., 467–470). Synopsis of a NADFS Spring lecture. Furnace design, operation and insulation are reviewed.

Production Furnace Turns Out Scale-Free Billets. H. C. Bostwick. (*Iron Age*, 1958, **182**, Aug. 14, 82–83). The "Equiverse" system of combustion and its application are described. The new system achieves a sufficiently high preheat temperature of combustion-air to obtain the temperature necessary to operate the burners with only 50% primary air for complete combustion; this is done by combining secondary combustion and regeneration with alternate firing of burners, first from one side of the heating chamber and then from the opposite side. The result is a strongly reducing gas in which steel can be heated without scaling to temperatures in the forging and extrusion range.—D. L. C. P.

Improved Method of Charging Slabs in a Plate Mill Reheating Furnace. V. P. Emel'yanov. (*Metallurg*, 1958, (9), 27). The author illustrates a good method of charging slabs so that the slabs in adjacent piles intersect each other instead of the individual piles having a space between them.—R. S.

Performance of Forsterite Refractories in Bottoms of Forge Reheating Furnaces. V. I. Sinyanskii, L. E. Solomon and P. D. Ionescu. (*Ogneupory*, 1957, **22**, (12), 568–571). Results of 5 years' trials are given. The average hearth life was 355 days and reasons for the improved performance are suggested. They are recommended for zones subject to the action of iron oxides and compare favourably with magnesite and chrome–magnesite.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Factors Influencing the Heat Treatment of High-Speed Steel. K. Wagner. (*Härt. Techn. Mitt.*, 1958, **12**, (3), 19–35). The behaviour of a number of high-speed steels when given various heat treatments was examined. The relation of hardness to impact and bend strength was studied for various hardening and tempering temperatures, and the results are discussed.

The Rate of Heating in Heat Treatment. B. A. Stetsenko. (*Metall. Obrabotka Met.*, 1957, (4), 47–50). Some tests made at the Gorki Automobile Plant to study the possibility of using rapid heating for hardening and tempering are described. The rate of heating of cylindrical specimens of fine-grain Cr steel (about 0·4%C, 0·9–1·2%Cr and 0·4%Ni) was studied. Data are given showing the effect of various heat treatments on hardness and impact strength.—R. S.

The Design of Air Blast Tunnel Burners. W. E. Francis. (*Gas Council Res. Commun.*, GC48, 1958, pp. 45).

Some Notes on Energy Transfer from Flames. G. Dixon-Lewis. (*Gas Council Res. Commun.*, GC58, 1958, pp. 17).

High Nickel–Chrome Alloys for Electrical Resistance Elements. (*Aciers Fins Spéc.*, 1958, July, 56–66). A survey of the types of nickel–chrome alloys used for furnace resistance elements, dealing with their properties, testing, and details of their application. (16 refs.).

The Design of High-Temperature Furnaces Using Graphite Elements. E. M. Haines. (*Industrial Carbon and Graphite*, 1958, 481–490, reprint). The design of vacuum and inert atmosphere furnaces is shown and design considerations are formulated.

Scientific-Technical Conference in Leipzig on the Heat Treatment of Metals. G. I. Pogodin-Alekseev, K. F. Starodubov and A. D. Assonov. (*Metallov. Obrabotka Met.*, 1957, (10), 53–63). The authors, who were the Soviet representatives at the annual Leipzig conference on heat treatment on 21–22 May, 1957, give detailed abstracts of the reports presented, including their own.—S. K.

Electrolytic Heating. *v.* Rotary Dip Heating. H. Mii, T. Sato and S. Funahashi. (*Rep. Gov. Ind. Res. Inst.*, 1957, **6**, July, 338–343). Heating by arc discharge from a rotating specimen dipping into an electrolyte solution was examined using a steel disc and compared with spray heating. The thickness is more important than the diameter.

Control of High-Speed Salt Baths. (*Metalen*, 1958, **13**, May 20, 90–91). [In English]. A description of the Brown Radiamatic-Electronik system for the measurement and control of salt bath temperatures.

Use of Sylvinite-Soda Melts in Salt Baths. E. A. Smol'nikov. (*Metallov. Obrabotka Met.*, 1957, (8), 40–42). The author describes tests on sylvinite-based baths with various additions for heating parts of 50Kh, ShKh15, U12 and U8 steels. These showed that sylvinite deoxidized with borax is satisfactory for parts to be quenched in water, aqueous NaCl or NaOH, or melts of KNO_3 or caustic alkalis, but results in a rather poor surface with oil quenching. For oil quenching 20% soda, should be added to the sylvinite and the baths deoxidized with sodium cyanide. The effects of sulphate impurities in the sylvinite were studied using cylinders of KhVG steel.

Bell Furnaces. (*Wild Barfield J.*, 1958, **6**, June, 10–13). An illustrated review of typical installations.

The Graphite Rod Resistor Furnace. T. A. Cosh and L. W. Sanders. (*J.B.S.C.R.A.*, 1957, Dec., reprint, pp. 10). A description of the design, operation and products from commercial furnace installations is given.

Influence of Design and Operation of Pusher-Type Furnaces on the Surface Quality of Steel. B. von Sothen. (*Stahl Eisen*, 1958, **78**, May 29, 733–736). In recent developments for the improvement of pusher-type furnaces emphasis was put more on output, thermal efficiency and service life than on the surface quality of the steel. The author presents a mathematical statistical method for evaluating the various effects of heat-treatment on the surface quality and its improvement.—T. G.

Ore Furnace Handles Two Operations Formerly Performed in Separate Units. (*Steel Proc.*, 1958, **44**, Mar., 161–162). A rotary hearth furnace for heat-treating ball bearing rings is described.

Automatic Knife-Blade Hardening Machine Treats 1500 Blades per Hour. (*Ind. Heat.*, 1958, **25**, Apr., 718). A moving hearth continuous gas-fired furnace is described.

Vertical Hardening of Axle Shafts. (*Metalw. Prod.*, 1958, **102**, July 25, 1304). An installation taking 32 tractor shafts each weighing 37½ lb in each of 5 pit furnaces with oil quench tanks is briefly described.

Hardenability Bands for Steels 8637-H to 8742-H. (*Met. Prog.*, 1958, **73**, April, 96B). Jominy curves are given for C–Cr and C–Mn steels.

Hardenability Bands for 9260-H to 9850-H (*Met. Prog.*, 1958, **73**, (5), May, 96B).

Heating Technique Minimizes Distortion. R. E. Wright and C. Schulenberg. (*Steel*, 1958, **142**, May 26, 102–103). Processes involved in hardening large gas turbine parts of Chromalloy steel are discussed on the aspects of eliminating distortion and minimizing changes in carbon content.—A. G.

The Influence of Ultrasonics on the Cementation of Steel. W. Rozanski. (*Arch. Hutn.*, 1958, **3**, (2), 125–146). A 0·12% C steel was used cemented in 70% charcoal, 20% $BaCO_3$ and 10% Na_2CO_3 mixture at 850°, 900° and 1000° C for 30, 50 and 120 min. The ultrasonic vibrations were applied when the required temperature was reached and maintained down to 600° C. At low intensities, diffusion rate is increased, above critical values graphite is formed especially where stresses are greatest and where fracture ultimately occurs. Structures are shown.

Heat Treating of Roller Bearings is Geared to Automatic Production. L. H. Everitt and O. E. Cullen. (*Met. Prog.*, 1958, **73**, June, 67–73). The 22 heat treatment furnaces in the production line of the Timken Roller Bearing Co., Bucyrus Ohio, are described. Gas carburizing of SAE 4620 steel is carried out in a completely automatic system.

Flame Hardening in Germany. H. Beike and E. Zorn. (*International Acetylene Assoc. Proceedings*, 1956, 84–96). A review of processes and equipment.

Nitriding at Weybridge. (*Wild Barfield J.*, 1958, **6**, June, 9). A brief account of an installation with a furnace of 30 in. diameter and 42 in. heated depth.

Fundamental Study on Cyaniding and Carbonitriding (1st Report). On the Cyaniding Gases. F. Yoshikawa, *Nippon Kinzoku*, 1957, **21**, Aug., 478–482). Samples of pure iron were cyanided. The recorded changes included comprise data on phase changes, micro-hardness and differential thermal dilatation.

Symposium on Annealing of Low Carbon Steel II. G. W. Form and E. B. Evans. (*Ind. Heat.*, 1956, **25**, Apr., 739–744). Papers are summarized which deal with the effect of variation in annealing cycle and composition on mechanical properties, European practice in annealing of coil and sheet, and costs in U.S. practice.

The Annealing of Tool Steel. J. J. van Herwijnen. (*Metalen*, 1958, **13**, May 31, 172–174). This final section deals with the influence of various combinations of annealing cycles, the initial hardness and structure and the influence of rate of cooling.

Bright Heating of Stainless Steels. I. M. Kawakami and M. Someno. (*Nippon Kinzoku*, 1957, **21**, Feb., 99–102). [In Japanese]. Results are reported for 18–8, 19% Cr and carbon steel heated in a hydrogen atmosphere containing a little HCl vapour. The higher the water vapour content, the more HCl is needed. With high amounts of HCl, high-temperature corrosion occurred. **II.** M. Someno. (**21**, Mar., 153–157). Stainless steel can be bright heated in an atmosphere of H_2 or N_2 containing titanium or silicon chloride. Changes in weight, microstructure, corrosion behaviour and mechanical properties of stainless steels heated in such atmospheres are reported.—K. E. J.

Increasing the Output of Tunnel Ovens in the Heat Treatment of Transformer Sheets. J. Kolofik. (*Hutnik* (*Prague*), 1958, **8**, Apr., 130–132). A comparison is made on the basis of production tests between the output of the tunnel oven described, when working at total throughput times of 4, 2 and 1·25 h, at temperatures increasing inversely with the time. For the last period, tests were made at two temperature levels. It is claimed that the quality of the sheet was improved, and was highest when treated at temperatures up to 980° instead of 780° C—the former maximum for the 4 h period. There was a marked increase in the furnace output.—M. T.

Salt Baths and Salt Bath Furnaces. H. Solakian. (*Met. Treating*, 1958, **9**, Jan.-Feb., 4–6, 49; Mar.-Apr., 8–9, 38–39, 52). Salt baths for use at 300–1150° F, the furnaces used and the purposes and results are surveyed. In Part II the range 1200–1800° F is covered.

Salt Baths: Use of Continuing Graphite Electrodes. (*Iron Steel*, 1958, **31**, May, 172). Brief details are given of the continuing graphite electrode bath recently developed by Efco-Upton. It enables electrodes to be renewed without taking down any of the furnace brickwork and allows the full life of the furnace lining to be utilized. Other advantages are summarized.—G. F.

New Furnace Takes 70-Ton Vessels. (*Ind. Gas*, 1958, **21**, July, 14). A gas-fired stress-relieving furnace for pressure vessels is briefly described.

Designing with Heat Treated Steels. J. L. Everhart. (*Mat. Design Eng.*, 1958, **47**, June, 121–136). Manual No. 149. Effects of annealing, normalizing, quenching and tempering, martempering and austempering are briefly described under the headings of heat treatments and the properties they give, selecting the steel and the design, fundamentals of the heat treatment of steel, and a glossary.

Direct Fired Coil Annealing Revives. (*Steel*, 1958, **142**, May 12, 94–96). Increased heating efficiency, reduced maintenance costs and the development of inner cover protective coatings are leading to greater use of the direct fired annealing process. New installations employ a baffle type burner of special design.—A. G.

Coils Opened for Annealing. (*Steel*, 1958, **142**, May 19, 144). To permit annealing gases to pass through coiled steel strips a nylon fishing line is wound into the coil and then pulled out.—A. G.

New Method Speeds Annealing. (*Met. Prog.*, 1958, **73**, June, 97–98). Cold rolled coils of mild steel are recoiled to provide spaces between laminations to accelerate heating and cooling. The coils are recuperatively heated in five stations and cooled in two stations of a rotary hearth furnace.

Bright Annealing in Electric Furnaces. O. Meyer-Witting. (*Elektrowärme*, 1958, **16**, Jan., 4–12). The evolution of the process and the atmospheres and apparatus used are outlined. Various installations are shown and the growing importance and simplicity of control of the method are stressed.

Metallurgy of Tempering and Annealing in Fractional Minutes. R. K. Wuerfel. (*Met. Prog.*, 1958, **73**, April, 93–96). Formulae are given for calculating the hardness obtained when oil quenched type 410 stainless steel is tempered for < 2 min. at 1140°–1435° F.

Study of Tempering Strains in High-Chromium Steels. C. Rovirosa. (*Mét. Constr. Mécan.*, 1958, **90**, July, 541–551). The results of measurements on several series of specimens are tabulated and discussed, and recommendations relating to the classification of steels are made.

The Efficient Temperature for the Tempering of Cold Deformed Steel 1Kh18N9T. Ts. N. Rafalovich. (*Metallov. Obra. Met.*, 1957, (12), 69–72). When heating this Cr–Ni steel, softening begins in the now completely deformed structure. The recrystallization structure which forms above 1000° appears less

clearly. With repeated cold-drawing, intermittent tempering must be carried out above 900°, because at this temperature the plasticity of the steel is considerably reduced and the deformed structure still persists.—L. H.

The Influence of Tempering on the Properties of Bainitic Steels. F. Staub and J. Tymowski. (*Hutnik*), 1958, **25**, April-May, 133–142)., Changes in the structure and properties of steels as a result of isothermal hardening and tempering with quenching in oil were noted, and a comparison was made between the behaviour of bainitic and martensitic steels in the light of mechanical tests and metallographic analysis with optical and electron microscopes of four constructional alloy steels. The hardness and tensile strength of bainitic steels fell more sharply as a result of tempering than those of martensitic steels, although in some instances the values were very close. The yield point of bainitic structures is always lower than that of tempered martensite or sorbite structures, and tempering does not vary this factor. The ductility (as expressed in terms of elongation and reduction in area) after isothermal hardening increases in proportion to the increase in tempering temperature. A comparison, however, of the reduction in area at the same tensile strength gives bainitic structures after low-temperature tempering a very small advantage over tempered martensite, while it changes to the disadvantage of the former with the increase in the isothermal transformation temperature. Tempering in the range 350–450° C can sometimes cause an appreciable fall in impact strength of isothermally hardened steels or those which have acquired bainitic structure by slow cooling. This also applies to those cases where rapid quenching to room temperature follows tempering.—M. T.

Effect of Tempering Prior to Quenching on the Properties of High Alloy Case Carburising Steels. Yu. G. Vyshkovskii. (*Metall. Obrabotka Met.*, 1957, (2), 23–27). Microhardness of the case and tensile strength of quenched, case-carburized specimens in which the retained austenite was first completely broken down by tempering at 350° C were not inferior to those specimens tempered at 650° C.—R. S.

The Distortion of High-carbon High-chromium Die Steel. K. Sachs and G. T. F. Jay. (*JISI*, 1959, **191**, Apr., 353–360). [This issue].

Fundamental Research on Heat-Treatment of Isothermal Transformation. III. Dilatometric Study on Quantitative Determination of the Fraction of Martensite and Bainite Below the Ms Point. Y. Mitani and N. Nakanishi. (*Nippon Kinzoku*, 1956, **20**, Mar., 147–150). An examination was made of 0·81%C steel after subzero treatment to remove retained austenite. Results of determining the fraction of martensite below the Ms temp. by the dilatometric method were in agreement with those by the point counting method.—K. E. J.

Study on Austempering of Structural Low-Alloy Steels. III. The Isothermal Transformation in the Intermediate and Martensite Ranges. H. Hotta and I. Tatsukawa. (*Nippon Kinzoku*, 1956, **20**, July, 368–371). Transformation diagrams for structural Ni–Cr–Mo steel and Cr–Mo steel were determined, and the relationship between isothermal transformation and retained austenite at room temp. was studied. In the intermediate range (330–500° C) austenite transforms to lower bainite, which breaks down to ($\alpha + \theta$). Below 300° C it transforms to martensite and then isothermally to lower bainite. After austempering at a fixed temp. in the martensite range, the retained austenite increases with holding time in the hot bath, reaches a max. at a period of lower-bainite formation and then decreases. (14 references).—K. E. J.

FORGING, STAMPING, DRAWING, AND PRESSING

Ways of Expanding Forging and Drop Forging Shops. V. A. Massen. (*Vestnik Mashin.*, 1958, (8), 32–38). After reviewing the latest installations in the U.S.A., notably at Ford's, Chevrolet and Dodge, the article studies conditions in the Soviet Union and suggests improvements in the heating of the metal, in the construction of the ovens, in the technology of forging and in the lay-out of the shops.—L. H.

Effects of Heat on Tool Steels During Hot Upsetting and Die Forging. G. Beck. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1556–1563). The author measured the rise in temperature of dies in the hot working of metals, and calculated the energy taken up by the dies. Heat transmission depends on the pressure in the die and on the surface roughness of the workpiece. The heat transmission values were used for prediction of the effects of heat on the tool steels of the dies.—T. G.

The Cold Sinking of Drop Forgings. K. Schimz. (*Maschinenwelt Elek.*, 1958, **13**, Sept., 315–319). The range of application of the technique and several illustrative examples are given.

Principles of Upsetting in Upset Forging Machines. P. Wasiunyk. (*Hutnik*, 1958, **25**, (7–8), 310–316). [In Polish]. Basic principles of upset forging are stated. The number of operations and their character are discussed for various ratios of free length of the bar l to its diameter d and for various final shapes of forgings. Corresponding formulae are deduced. A few numerical examples are solved.—S. S.

The Industrial Use of Knowledge of the Formation of Internal Cracks in Large Forgings. M. Bakala. (*Hutn. Listy*, 1958, **13**, (9), 786–795). The divergence of opinions on this subject is great. Isothermal cooling is recommended as the best treatment to avoid such faults, but the problem of determining the appropriate temperature is complex, as it varies so greatly, and all the various reasons for the occurrence of crystallization cracking and unwelded blow-holes are not entirely established. Faults in medium and large forgings can, however, be controlled by modern non-destructive methods of analysis, e.g. ultrasonic testing.—M. T.

One-Piece Wheels: Their Production and Uses. (**Technique Moderne*, 1958, June, 249–252). The method of manufacturing railway wheels is outlined in relation to requirements to be complied with. The installation is described. Thermal treatment and the properties obtainable are discussed.

Methods Used in Precision Stamping. Oehler. (*Techn. Mod.*, 1958, **50**, Oct., 446–450). The application of punches to obtain polished surfaces is described and the arrangement of press tools is shown.

Explosives Form Space Age Shapes. (*Steel*, 1958, **143**, Aug. 25, 82–86). Explosion-forming is proving very useful for certain types of work, particularly those which are difficult or impossible by other methods; examples are given. Most of the work involves cartridges, powder charges, shaped charges or high explosives with or without the use of tools. The method is being used to forge, extrude, coldweld, pierce holes, cut large billets, work-harden, emboss, flatten sheets elongate carbon steel 70% (normal limit 42%) and to compact powdered metals.—D. L. C. P.

Coefficient of Reduction and Real Stresses in the Walls in Drawing. B. Wassilieff. (*Technique Moderne*, 1958, June, 217–218). The author gives a critical discussion of the mathematics connected with drawing. The ratio of diameter of draw to thickness of sheet is important and related to the coefficient of friction. Real stresses in the walls of a draw are taken as a criterion for drawing capability. Examples for calculating the coefficient of reduction for a given relative diameter of draw are quoted.—R. P.

Working Machine Parts by Rollers to Raise Their Strength and Resistance to Wear. A. I. Barats. (*Metallov. Obrabotka Met.*, 1957, (9), 47–51). Equipment and conditions for rolling surfaces are described and the effects of this treatment on dimensions, hardness at various depths below the surface, and microstructure are dealt with. Some practical examples are given.—S. K.

The Stability of Tube Drawing when Using a Self-Regulating (Floating) Mandrel. I. L. Perlin. (*Tsvetnye Metally*, 1958, **31**, (9), 58–61). The stability of the tube drawing process when using a self-regulating mandrel increases in proportion to the reduction in the angle of taper of the mandrel and that of the reducing die, and with the reduction in the coefficient of friction. With the increase in the angle of taper of the mandrel, the length of the cylindrical part of the mandrel should also be increased and *vice versa*. With the reduction in the diameter of the barrel of the mandrel the length of its cylindrical part should also be reduced and *vice versa*. Drawing of tubes with a self-regulating mandrel should be carried out: (*a*) at the smallest possible angles of taper of the reducing die and of the mandrel subject to the condition that the tangent of the angle of taper of the mandrel is greater than the coefficient of friction, but which will ensure an admissible reserve strength factor for the drawn part of the tube, and (*b*) with the use of all possible measures to reduce the coefficient of contact friction by polishing and lubrication.—M. T.

Production Technology of Steam Turbine Blades by Rolling and Drawing Methods. J. Nowotarski and R. Wusatowski. (*Prace. Inst. Hutn.*, 1958, **10**, (4), 199–207).

The Transformation of Sheet Metal in the Automobile Industry. T. Philippe. (*Technique Moderne*, 1958, June, 219–230). This first part of the paper deals with the general problems of sheet metal working in the car industry, particularly at the Renault works. The requirements of car parts consisting of sheet metal are discussed and related to the properties and composition of the metals used. Permissible limits are stated. Cutting, piercing, bending drawing and blanking operations and machinery are discussed.—R. P.

Calculation of the Drawing Forces in Wire Drawing. O. Pawelski. (*Stahl Eisen*, 1958, **78**, Oct. 16, 1471–1472). The author reviews very briefly various concepts of the calculation of the drawing force in wire drawing, published in the literature. The results of the calculations for various die angles are plotted, together with experimental values. The error is within 10% if the reduction of area is greater than about 10%, for reduction smaller than 10% too high a value is obtained.

Friction in Wire Drawing. W. Dahl. (*Stahl Eisen*, 1958, **78**, Oct. 16, 1471). Recent work of Weiler and Likhtman is reviewed and disputed, and an error in an equation for the drawing force pointed out.—T. G.

Extruded Steel Sections Obtained by the Ugine-Sejournet Process. G. Leclerc. (*La Technique Moderne*, 1958, June, 243–248). The principles of extrusion are discussed and the importance of glass lubricants is stressed. The extrusion of various sections from carbon steels, low-alloy, heat resisting and Nimonic alloys is discussed, including blades for the aircraft industry.—R. P.

ROLLING MILL PRACTICE

Elongation and Spread during Hot Rolling of Low Carbon Steels with Large Draughts. Z. Wusatowski and B. Hoderny. (*Arch. Hutn.*, 1958, **3**, (3), 161–179). Rolling with draughts between 50–90% with sections 20 × 20, 20 × 40, 15 × 100 and 10 × 110 mm at 900°, 1000°, 1100° and 1200° C was studied with measurements of elongation, spread, forward slip, rolling speed, pressure and torque and structures, were examined also. Width and length charges and thickness are here considered. **The Forward Slip and the No Slip Angle during the Rolling of Low Carbon Steels with Large Draughts.** Z. Wusatowski and F. Kunert. (181–199). Further calculations are made on the basis of the foregoing measurements and an expression is developed and the constants evaluated.

The Intensity of Deformation during Rolling Z. Wusatowski. (*Prace Inst. Hutn.*, 1958, (2), 120–123). The author defines intensity of deformation and evolves formulae to calculate this factor, during rolling on a slip or

non-slip plane. An example is given of the analysis of the rolling of a test-piece and the determination of the deformation intensity. The method described enables not only the vertical velocity as well as the deformation intensity to be correctly determined, but also the degree of deformation along the arc of contact. It was established that the main differences between the vertical velocities and intensities of deformation during rolling on slip and non-slip planes exist in the zone of retard. These differences in the dividing surface disappear, as in the zone of advance only inconsiderable values are apparent.—M. T.

An Analysis of Friction Forces and Roll Engagement in Disc Mills. P. K. Teterin. (**Stal'*, *Rolling and Tube Manufacture Supplement*, 1958, 207–226). A mathematical analysis is presented and the equations derived are discussed.

The Distribution of Deformation Resistance Along the Pressed Arc in Rolling Operations. S. Geleji. (*Kohászati Lapok*, 1958, **13**, Feb.-March, 70–72). A calculation method, allegedly hitherto unknown, is given for determining the distribution of deformation resistance along the pressed arc in rolling operations, thereby giving the maximum deformation resistance.—F. K.

Stress Conditions in Oblique Rolling. I. A. Fomichev. (**Stal'*, *Rolling and Tube Manufacture Supplement*, 1958, 176–206). In oblique rolling, defects can occur in the cross-section of the workpiece. A reduction of 2–12% causes a regularly disposed rupture in the core, sometimes only at the ends. These have been referred to shearing stresses and to normal stresses by different authors. It is now found to be unsymmetrical and uneven. An examination of stress conditions is made on a Cr–Ni–W–Mo steel billet with and without a plug and this appears to confirm uneveness of plastic deformation as the cause. The occurrence of circular break-up is discussed.

Automatic Contour Turning of Large Mill Rolls. W. Hyams. (*Iron Steel Eng.*, 1958, **35**, March, 82–88). The author describes a large 44-in. screw-feed roll lathe with automatic contouring equipment. Although there are only four such machines in operation in the iron and steel industry, the author suggests that much more use will be made of this type of equipment in the future.—M. D. J. B.

Use, Manufacture and Heat Treatment of Alloy Cast Steel Rolls. III.—Technology of the Manufacture of Cast Steel Rolls. H. Uhlitzsch and G. Radomski. (**Neue Hütte*, 1958, **3**, Aug., 475–482). In this section a numerical example is given of the use of the formula developed theoretically in Section I. (1957, **2**, Nov., 655–664). By the use of the formula a heat-treatment programme can be worked out for any given case of a low-alloy cast steel roll. The method has been used satisfactorily by the author in 45 cases.

An Analysis of Existing Methods of Roll Profiling for Hot and Cold Pilger Mills. P. K. Teterin. (**Stal'*, *Rolling and Tube Manufacture Supplement*, 1958, 227–242). A mathematical study of cone profile and rolling conditions is presented, using the methods of Emel'yanenko for hot rolling and for cold rolling and of Verbitsky.

Use of Inductive Heating in the Mounting and Dismantling of Bearings in Rolling Mills. W. Völkening. (*Stahl Eisen*, 1958, **78**, Aug. 21, 1181–1186). Devices for dismantling and mounting various types of bearings of rolling mill rolls are described, in particular, devices using inductive heating at mains frequency and either 380 or 20–40 V according to the size of the bearing. Hydraulic devices and ring-shaped gas burners are briefly dealt with and the costs of the different methods compared.—T. G.

Flywheel Selection for Rolling-Mill-Trains. E. Kiss. (*Kohászati Lapok*, 1958, **13**, Feb.-March, 131–135). The principles of flywheel selection for rolling-mill trains are given, based on power consumption and operative conditions.—F. K.

Manufactured of Profiled Sections by Cold-Rolling of Metals. Applications of Profiled Sections. U. Rouse. (*Technique Moderne*, 1958, June, 238–242). Bending, drawing and rolling are briefly compared as methods of cold working. The various stages in cold rolling are described and applications of cold rolled sections are indicated.—R. P.

The Influence of the Degree of Eccentricity in a Stiefel Piercing Mill on the Possible Formation of External Spiral Defects during Piercing. V. Dedek. (*Hutn. Listy*, 1958, **13**, (10), 882–892). An examination of the theory of the piercing process is followed by a description of experiments to examine the causes of the formation of external spiral defects. They were found to increase in proportion to the increase in the degree of eccentricity.—M. T.

Pipe Mills at the Anzin Factories of the Société Lorraine-Escaut. M. Gouy. (*Technique Moderne*, 1958, June, 270–273). The plant is described and consists mainly of storerooms, piercing press, furnaces, Pilger mill, straightening rolls, finishing and inspection department.—R. P.

Production of Seamless Casing and Tubing. M. Sumrall. (*Iron Steel Eng.*, 1958, **35**, March, 138–139). This paper describes the seamless mill at the Colorado Fuel and Iron Corp. capable of producing casing of 4½–9⅝ in. outside diameter for oil well sinking.—M. D. J. B.

Installation of Stretch Reducing Mill. H. L. Mitchell. (*Iron Steel Eng.*, 1958, **35**, March, 139–141). The installation of stretch reducing equipment enabled much greater outputs to be achieved on a 4½ in. outside dia. seamless tube mill. The stretch mill is a 16 stand installation.—M. D. J. B.

Rolling Copper-Plated Steel Tubes. F. Storek and J. Prošek. (*Výzkumné Práce z Oboru Železa a Oceli*, *State Publ. Ho. Tech. Lit. Prague*, 1958, 149–155). [In Czech]. Details are given of research and development work which led to the possibility of producing internally copper plated tubes directly by hot rolling. Tubes with bores of 4·6–8·6 cm, wall thickness of 0·3–1·0 cm, and copper coat of thickness 0·05–0·1 cm can be rolled; by subsequent cold drawing the dimensions can be reduced to bores of 1·2–8·4 cm, wall thickness not less than 0·2 cm and coat thickness of 0·02 cm.—P. F.

Electrical Drive System for a High Speed Combination Rod Mill. A. F. Kenyon and H. J. Oakes. (*Iron Steel Eng.*, 1958, **35**, March, 123–135). The mill drive arrangements at the Cuyahoga Works of the American Steel and Wire Div. of U.S. Steel Corp. are described. The motors, power supply rectifiers, ventilation and control equipment are discussed.—M. D. J. B.

The Drive and Control of a Cold Strip Reversing Rolling Mill. W. Grzybowski. (*Hutnik*, 1957, **24**, Sept., 363–369). [In Polish]. Problems of the drive of four-high reversing mills are discussed. The advantages of automatic control of the rolls in order to obtain a cold strip of constant thickness is pointed out.

Modern Control of Rolling-Mill Drives. J. Soukeník. (*Hutn. Listy*, 1958, **13**, (7), 620–625). The various types of electric motors and methods of operating them are critically surveyed.—P. F.

Use of Plastics for Articulated Spindles, Coupling Boxes and Clutches in Rolling Mills. T. Burdelski. (**Stahl Eisen*, 1958, **78**, Aug. 7, 1110–1119). The use of shock-absorbing coupling members made of plastics reduces impacts in the drive system and the specific pressure in mechanical contacts, thus reducing wear and noise. The properties of a number of plastics are reviewed and their behaviour under pressure discussed. Examples of their proper use are given together with results obtained in reducing wear. Proper lubrication of the plastic elements is emphasized.

Determination of Power Demand of Roller-Sheet-Straightening Machines. S. Geleji and G. Dévényi. (*Kohászati Lapok*, 1958, **13**, Feb.-March, 111–117). A calculation method is given for determination of the power demand of roller-sheet-straightening machines. The results obtained agree with those obtained by actual measurement.—F. K.

Shearing Lines. R. Lucas. (*Technique Moderne*, 1958, June, 275–283). The author describes the installations, operations and uses of shearing lines.—R. P.

Control Equations of Multistand Cold Rolling Mills. G. Lianis and H. Ford. (*Proc. I.M.E.*, 1957, **171**, (26), 757–776). Changes of interstand thickness, tension and final output with changes of ingoing gauge, coiler tension, roll gap setting and roll speed are formulated. Nomographs are developed and examples given.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Handling Materials Within the Steel Plant. (*Higher Productivity*, 1958, **2**, July-Aug., 17–21). A brief illustrated review of conveyor systems for coils, with notes on the transport of billets, sheets, tubing, wire etc.

Casting Cranes of the Heaviest Construction. F. Adams and K. Schmoll. (*Demag Nachrichten*, 1958, (151), 16–20). A description of the structural details of the two heavy cranes of steelworks III of August-Thyssen-Hütte are described.

Bar Steel Storage Racks Save Time, Trouble; Offer Space Savings for Bethlehem Shipyard W. Lindbeck. (*Western Metalw.*, 1958, **16**, Aug., 36–37).

WELDING AND FLAME-CUTTING

Welding of Malleable Cast Iron. H. Maeder. (*Forsch. Wirts. Nordrhein-Westfalen*, 1957, No. 328, pp. 79). Various kinds of malleable iron with thicknesses from 6–12 mm were welded in various ways and directions for avoiding cracks are given.

Oxy-Acetylene Welding of Iron Castings. B. Lonati. (*Fonderia*, 1958, **7**, May, 225–228). [In Italian]. The author reviews the weldability of various types of iron and stresses the need for preheating and preparing the parts to be welded. Burner design and the nature of metals of addition are discussed. Results of experiments and tests are given.

The Welding and Annealing of Spheroidal Graphite Cast Iron. R. Müller. (*Giess. Tech. Wiss.*, 1958, Apr. 1049–1065). Investigations are described on the annealing of spheroidal graphite cast iron for ferrite and pearlite formation. The chemical compositions of these cast irons is discussed. Electric arc welding, oxy-acetylene welding and consumable electrode welding have been investigated. The metallographic texture, mechanical properties and the effect of annealing in the neighbourhood of the weld were studied in each case. (28 references).—R. J. W.

Progress in Steel Welding. G. Grenier. (*Echo Mines*, 1958, July, 437–438). Historical introduction and discussion of general principles with examples. Both oxy-acetylene and arc processes are touched upon.

The Practical Application of Present-Day Advances in Welding Metallurgy. I. Chabelka. (*Avtom. Svarka*, 1958, (6), 3–12). Consideration is given to the weldability of constructional steels, and the effect of the rapid heating and cooling process on the properties of the heat-affected zone, the influence of the content of gases in the steel and of other factors during various technological welding processes are analysed. A general exposition is given of phase changes in the heat-affected zone, local cooling phenomena, the influence of various gases and particularly of H_2 and O_2 on the structure of the metal, and the formation of martensite. Special comments are made on submerged arc welding and electric slag welding. Since in submerged arc welding the heat-affected zone is much smaller and fusion of the base metal takes place very rapidly, the phase transformations and other phenomena of the welding process occur more abruptly, which has a detrimental effect on the structure and properties of the weld, and the influence of segregation of additions and gases and of their migration is greater than in shielded metal-arc welding; unstable oxides and sulphides also frequently break down during this welding process, and the high heat transfer rate causes brittleness and cracking. Electric slag welding, on the other hand, provides conditions in which influences on the heat-affected zone are dreuced to a minimum.—M. T.

Gas Shielded Self Adjusting Arc Welding as Applied to Steels. H. Levinsohn. (*N.Z. Eng.*, 1958, **13**, July 15, 273–278; Aug. 15, 307–310). The process, equipment, variables and properties of the welds produced are reviewed, with a section on stainless steel. Mild steel is then considered and advantages, limitations and costs are considered with a note on health hazards. The use of A is described and difficulties with CO_2 are noted although it seems economically more attractive.

Lowering the Hardness of the Transition Zones in Welds of Low Alloy Boiler Tubes. V. Šmíd and R. Šejnoha. (*Zváranie*, 1958, **7**, (6), 161–168). Experimental evidence was obtained showing that a comparatively large zone in the vicinity of the weld in thin-walled tubes reached a temperature of 900–950° C, and that rapid cooling after welding resulted in the formation of considerable amounts of bainite and martensite. These are responsible for the observed hardness. In thick-walled tubes hard phases are produced to a lesser extent because of lower cooling rates. Complete local austenitization cannot be avoided, but a reduction in the amount of hard phases formed is attainable by pre-heating the weld zone. In the discussion of these recommendations, following the paper, J. Lombardini points out that hardness is not the only criterion for assessing weld quality, and that the presence of bainite is only one of the contributors to the increased hardness. Preheating of low-alloy Cr–Mo–V steels above 400° C as suggested by the authors, would in fact increase the tendency to the formation of welding cracks even though the heat treatment should result in a reduction of the hardness. The metallurgical reasons for this and similar behaviour in other steels are discussed.—P. F.

Effect of Arsenic on the Weldability of Low-Carbon Steels. A. G. Kalashnikov. (*Stal'*, 1958, (8), 736–739). Conditions for forge welding without the use of flux are shown for As contents up to 0·29% with bars not thicker than 20 mm. Rimming steel in thin sections seemed to be more difficult to weld than killed steel. With 12 mm strip the As had no adverse effect but with 20 mm it was somewhat more difficult and deteriorated with increasing As, but it is concluded that with care welding can be made satisfactory with up to 0·29% As.

The Effects of Porosity on Mild-Steel Welds. W. L. Green, M. F. Hamad and R. B. McCauley. (*Weld. J.*, 1958, **37**, May, 206s–209s). The effects of porosity on the mechanical properties of arc welds in mild steel were investigated. It was found that the cross-section of the welds tested could be reduced by up to 7% without materially affecting the mechanical properties measured. Size or amount of the porosity was the most important factor and its shape and distribution had little effect.—B. C. W.

How to Braze Stainless Steels. Part IV. H. M. Webber, (*Ind. Heating*, 1958, 25, May, 895–905). The types of gas atmosphere employed for bright brazing are described together with the equipment used to generate them.—A. G.

Computer Cuts Steps in Flame Profiling. (*Iron Age*, 1958, **181**, May 1, 90–91). The operation of a new flame cutting unit is described. From the drawing of the part a planning sheet is prepared and this information is teleprinted on to paper strip from which a computer produces magnetic tape. The tape is fed to the cutting machines console, which controls the movement of the torch and makes other adjustments. The production machine handles plates up to 12 × 40 ft.

Flame Grooving with a Carbon Electrode and Compressed Air. J. Škriniar. (*Zváranie*, 1958, **7**, (6), 171–175). [In Slovak]. Details are given of modifications to carbon-arc welding torches facilitating their use for flame gouging. The method is suitable for grooving the roots of welds, scarfing and cutting, particularly where cutting with oxygen is difficult. The method is cheap and versatile; the modifications to the torch are easily carried out in any workshop.—P. F.

MACHINING AND MACHINABILITY

Free-Machining Annealed Grey Iron. A. Whitmore. (*Brit. Found.*, 1958, **51**, Aug., 385–387). The machinability of grey iron depends more on the microstructure than on the mechanical properties. The greater the percentage of ferrite in the matrix the greater the ease of machining; the graphite should be in the coarsest possible form. Annealing to obtain these desired properties is described. The advantages gained in the machine shop are discussed, e.g. cutting speed, tool life, etc. However, the reduction in physical properties owing to the annealing are a limitation to its application.—T. G.

The Effect of Tool-Chip Contact Area in Metal Machining. H. Takeyama and E. Usui. (*Trans. A.S.M.E.*, 1958, **80**, July, 1089–1096). It is shown, theoretically and experimentally, that the tool chip contact area per unit area of cut is closely related to the shear angle, and is a controlling factor in metal machining.

Preform Blanks From Bar Stock To Cut Machining Costs. (*Iron Age*, 1958, **182**, Aug., 14, 84–86). The use of preformed cold worked blanks for multi-diameter parts may lead to advantages in machining, material savings, and quality; the possibilities of this are explained, with examples.—D. L. C. P.

Machining Time Trimmed 22%. (*Steel*, 1958, **143**, Aug. 18, 112). The use of hot extruded, cold-drawn steel bars for making split clamping rings is described. Round stock required 3 extra milling and grinding operations. Cost saving is 18%.—D. L. C. P.

The Optimum Geometry of the Face Cutter and the Milling Process for Forging Steels. I. N. Kosenko. (*Vestnik Mashin.*, 1958, (8), 54–56). The specimens under test were of steel 5KhGM of hardness 205 HB. The milling was carried out non-symmetrically against the direction of the feed. The single-toothed cutters of 234 mm dia. were of heavy alloy T15K6. Some cutters with 2, 3, 4 and 6 slots were also tested. Tests were carried out on a vertical mill. The criterion for blunting was taken as 1 mm wear on the rear facet of the tooth of the cutter. The wear was measured with a special binocular microscope permitting measurement without demounting the blade. Details of tests are given and results tabulated.—L. H.

Forged Tool Steels for Hot Working. P. Wagener. (*Rev. Tech. Luxembourg*, 1958, **50**, July-Sept., 157–179). The requirements for good tools are set out and the effects of alloying elements and of heat treatments are considered. Annotated tables of steels, their makers, compositions, treatment and uses are then given, 164 materials are included, British, French, German and U.S.

Face Milling of Sulphur Iron with Cermet Blades. D. N. Troitskaya. (*Vestnik Mashin.*, 1958, (8), 51–52). Cermet compacts with an impact breaking strength of 36·6 kg/mm² and a specific gravity of 3·9 g/cm³ were tested on a special vertical milling machine powered by an electric motor. The material milled was a specially cast sulphur iron of hardness 170–179 HB. The optimum operational speed was found to be 282 m/min with a rate of feed of 0·04 mm. The relation between the resistance of the blade and the cutting angle is given graphically.—L. H.

Cutting Power of Cast and Hot-Worked High-Speed Steel Tools and Their Metallurgy. K. A. Krekeler. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1575–1585). Cutting tests showed that cast high-speed steel tools have a better cutting power than hot-worked tools, if the temperature rise at the tool tip is only moderate and if they have the correct carbon content and are diffusion-annealed. The carbon content should be 10–20% higher for cast tools than for hot-worked tools made of steels of the same nominal composition. At high cutting temperatures the cutting power of the cast tools decreases more rapidly than that of hot-worked tools, the reason being the deformation of the carbide grain-boundary network owing to the hardness decrease of the matrix.—T. G.

Some Remarks on the Formation of Cracks When Grinding and the Methods for Revealing Them. I. H. Schwartz. (*Met. Constr. Masini*, 1958, **10**, (7), 564–569). [In Rumanian]. The mechanism of fissure formation is explained as are also the factor which influence their appearance, i.e. factors deriving from the original structure and those deriving from the heat treatment according as these latter are generally applicable or only as originating under special heat-treatment conditions. Under these two headings the article considers the influence of residual austenite, the temperature of tempering, overheating, internal stresses due to faulty heat-treatment, the cementite lattice, the lattice of carbides of the alloy elements, decarburizing, etc. and also the special factors such as cementite grains, coarse structure, non-metallic inclusions and sharp variations in the carbon content between the core and the surface of the metal.—L. H.

The Cold Cutting of Rolled Shapes with Friction Saws. A. Wolf and D. Härtl. (*VDIZ*, 1958, **100**, Oct. 21, 1437–1443). Tests on two friction saws have shown that the cutting efficiency of the saws is influenced by the shape of the disc, the cutting speed, the feed rate, and the thickness of the material. Cutting in an oxygen atmosphere improves the cutting surface. Methods of reducing noise in cutting are briefly described.—L. J. L.

Behaviour of Cutting Fluids in Reaming Steels. L. V. Colwell and H. Branders. (*Trans. A.S.M.E.*, 1958, **80**, July, 1073–1078). Torque and roughness measurements in reaming tests showed that some lubricants may reduce the size of built-up edges so that substantial rubbing can occur between the wall of the hole and the reamer margin. Torque requirements increase, and hole size and surface roughness decrease with increased lubricant effectiveness.

Wear of Carbide Tools and Surface Finish Generated in Finish Turning of Steel. V. Šolaja. (*Wear*, 1958, **2**, Aug., 40–58).

The Manufacture of Tools with Spark Erosion Machines. H. J. Schulz. (*Giesserei*, 1958, **45**, 25 Sept., 615–623). The principle and mode of operation of spark erosion equipment are described in detail, and illustrated by several examples. The economics and possible developments of the technique are outlined.

CLEANING AND PICKLING

Applications for Alkaline Descaling Cleaners. E. R. Jorczyk. (*Met. Fin.*, 1958, **56**, Oct., 46–48, 55). The equipment used, solutions and application to carburized and hardened parts and to the removal of rust and scale are described. Proprietary descaling cleaner and NaCN are used.

Two Shipyards Install First U.K. Airless Shot Blast Plants. (*Ind. Fin.*, 1958, **10**, Aug., 27–29). Yards at Middlesbrough and Sunderland have put in mechanical shot-blasting equipment for large plates, which are illustrated and described.

Autoflow Machine for Automatic Vapour Blasting Treatment. (*Machinery*, 1958, **93**, Aug. 27, 482–484).

New Pretreatment Thwarts Rust. H. W. Adams. (*Iron Age*, 1958, **182**, Sept. 18, 86–87). A patented three-materials system is mentioned, which removes rust and renders the metal surface passive, non-conductive and well primed ready for painting.—A. G.

Electropolishing. J. F. Jumer. (*Met. Fin.*, 1958, **56**, Aug., 44–47; Sept., 60–63). The mechanism, techniques and operations are described in general terms and many published bath compositions are given, largely from patents.

Self-Adhesive Tapes in Metal Finishing. (*Electropl. Met. Fin.*, 1958, **11**, Sept., 303–308; Oct., 359–364). Uses for masking in spraying, polishing and abrading, plating and anodizing are considered. Types of strip materials are discussed. In the second article, uses are illustrated and materials tabulated.

PROTECTIVE COATINGS

Electroplating Explained—A Course for the Working Plater. H. Hartley. (*Prod. Fin.*, 1958, **11**, April, 96–102). The measurement of specific gravity, temperature and pH is described together with the significance of these factors in the plating process.—A. G.

Preparation of Samples in Studies of Metallic Coatings. K. Otypka. (*Sbornik-Ostrava*, 1957, **3**, (3), 39–46). [In Czech]. Various methods of sectioning, etching and isolating surface coatings, used in University laboratories in Ostrava, are described.—F. F.

Examination of Electrodeposits for Pores. D. Horstmann. (*Stahl Eisen*, 1958, **78**, Oct. 16, 1476–1478). The author reviews recent publications on porosity tests for electrodeposits on ferrous and non-ferrous metals. The principle of each test is briefly described. (47 references).—T. G.

Porous Deposits of Chromium Obtained in Sulphate Baths. E. Thurby, J. Dale and H. Benninghoff. (*Chrome Dur*, 1958, April, 6–20). The effect of such variables as sulphate content of the bath, temperature, current density and chromic acid content on the porosity of Cr deposits has been investigated and results are reported.—A. G.

Cold Chromium Plating of Moulds of Large Surface Area. M. E. Goldstein. (*Chrome Dur*, 1958, April, 1–6). Results are reported which show that with a cold electrolyte a current density $\frac{1}{3}$ to $\frac{1}{4}$ of the normal value is adequate. The optimum composition of the electrolyte is 250 g/litre of CrO_3 and 4 g/litre of NH_4F. Covering power is superior and the technique is recommended for plating dies and complicated parts of large surface area.—A. G.

Experiments on the Electrolytic Deposition of Metallic Chromium from Chromic Salt Solutions. II. Influence of the Form of the Chromic Ion on the Deposition of Chromium. S. Morioka and H. Yamaoka. (*Technology Reports of Tôhuku University*, 1958, **22**, (2), 173–186). [In German]. Comparative tests were carried out on the electrolytic reduction of chromium salts in the form of sulphate, nitrate and chloride. The reducibility of the violet and green sulphate forms were compared, together with the comparative effects of ammonium sulphate additions.

Fresh Look at Plating Problems. (*Met. Prog.*, 1958, **74**, July, 112–114, 146–156). *Inter alia*, surface preparation before plating is emphasized and details of tests and results of shot peening of steel before Cr-plating are reported, with respect to improvement of the fatigue strength of high-strength steel and of the fatigue limit of medium-strength steel. Heating at 375° F for 3 h of shot-peened, Cr-plated steel gives a slight increase in fatigue strength.—T. G.

Bright Nickel Plating—Deposit Characteristics. D. J. Fishlock. (*Prod. Fin.*, 1958, **11**, April, 79–90). Characteristics of an ideal bright nickel process are listed and the effect of variables on throwing power, deposit structure, internal stress etc. is considered. The causes of such imperfections as roughness pitting and porosity are discussed.—A. G.

Stress in Nickel Electrodeposits. T. P. Hoar and D. J. Arrowsmith. (*Trans. Inst. Met. Fin.*, 1958, **36**, autumn, 1–6). Tests were made continuously on deposits from a plain Watts' bath and from baths containing stress-reducing agents. The stress falls and becomes compressive as the concentration of agent is increased. Interpretations on vacant-site and dislocation theory are put forward. Various sulphonic acids were used as stress-reducers.

Chemical Nickel Plating. R. Orlowski. (*Usine Nouv.*, 1958, **14**, May 22, 101). An outline of the process for depositing non-electrolytically a coating of nickel on large objects. The physical and chemical properties of the deposit and some applications are described.

Rapid Quantitative Methods for the Determination of Brighteners, Levellers and Anti-Pitting Agents in Nickel Electroplating Baths. K. Szmidt, T. Zak and Z. Kwiatkowski. (*Trans. Inst. Met. Fin.*, 1958, **36**, Autumn, 17–21). Polarographic and surface tension methods are used.

Hot-Dip Galvanising. New Knowledge and Results. H. Bablik. (*Österreichische Ingenieur Z.*, 1958, **1**, Feb., 91–96). The composition of the zinc coating, the effect of the composition of the base metal and new developments in the automation of the hot-dip galvanizing process are amongst the topics discussed.

Galvanizing in a Cyanide Electrolyte and the Mechanical Properties of Steels. I. I. Moroz and N. T. Kudryavtsev. (*Metallov. Obrabotka Met.*, 1957, (8), 28–33). In this work the influence of electrochemical treatment in galvanizing on the physical and mechanical properties of steels (types 30KhGSA, 38KhA, 12Kh2N4A, 30Kh2N2VA) and technical iron, were determined in relation to their composition. The greater hydrogen-absorbing capacity of high strength steels led to a greater change of mechanical properties than with the more ductile steels; the deterioration being the greater the longer the duration and higher the current density of the galvanizing process. The properties were not affected by preparatory treatment.—S. K.

Galvanised Steel in Building and Public Works. J.-R. Rouff. (*Corros. et Anticorros.*, 1958, **6**, June, 211–216). The use of hot-dip galvanizing in building is described, with some applications. The principal characteristics of the zinc coatings and the type of protection given are outlined.

POWDER METALLURGY

Sintered Materials on the Base of Iron with Special Regard to Alloyed Sintered Steels. R. Kieffer and F. Benesovsky. (*Nat. Metallurgical Lab. Council of Sci. and Ind. Res., Jamshedpur*, 1958, 343–361). The production of sintered iron and steel parts is outlined and the properties of iron, carbon and alloy steels, (Cu, Ni and Mn and stainless), are given.

Porous and Infiltrated Metal. J. E. Elliott. (*J. B'ham Met. Soc.*, 1958, **38**, Sept., 105–128). A review of powder metal components for all purposes, including Fe–Cu compacts.

Convertible Rolling Mill Compacts Powders into Sheet and Strip. (*Iron Steel Eng.*, 1958, **35**, March, 171–172). A newly developed horizontal rolling mill which compacts metal powders directly into sheet and strip and which is also convertible to a vertical 2-high-4-high combination mill is described. The mill handles materials up to 7 in. and in thicknesses from $\frac{1}{16}$ in. to $\frac{1}{4}$ in.—M. D. J. B.

Sealed Units Aid Processing of Powdered Products. (*Iron Age*, 1958, **182**, Aug. 14, 88–89). The use of large bins and hoppers for handling metal powders is described. These are designed to allow convenient storage and handling and also dust-free discharge to the processing system.—D. L. C. P.

FERRITES, CERMETS AND CARBIDES

Ferrite Bibliography. (*Min. of Supply TIL/BIB/27*, 1958, March, pp. 10). A list of the unclassified reports with brief abstracts.

Ferromagnetic Resonance in Some Ferrites at Low Temperatures. N. I. Krivko. (*Zhur Tekh. Fiz.*, 1958, **28**, (8), 1703–1710).

Permanent Magnet Oxides Containing Divalent Metal Ions. II. L. G. Van Uitert and F. W. Swanekamp. (*J. Appl. Phys.*, 1957, **28**, Apr., 482–485).

A Theory of the Magnetic Annealing Effects in Ferrites. I. General Theory. II. Application of the General Theory in Special Cases. S. Taniguchi and M. Yamamoto. (*Nippon Kinzoku*, 1956, **20**, Sept., 503–507; 507–510). I. A theory of ferromagnetic uniaxial anistropy induced by magnetic annealing in cubic solid solutions is extended to ferrites. The concentration-dependence of the magnetocrystalline anisotropy constant in certain binary ferrites is discussed. (17 references).

II. The extended theory explains satisfactorily results on induced uniaxial anisotropy as depending on concentration, orientation of the field during annealing and temp. of annealing. The anisotropy is therefore caused by an anisotropic distribution among cations and cation vacancies.—K. E. J.

Molecular Field Fluctuation Effects in Mixed Nickel–Zinc Ferrites. D. M. Grimes, S. Legvold and E. F. Westrum, jun. (*Phys. Rev.*, 1957, **106**, June 1, 866–867).

The Production of Single Crystals of Ferrites According to Verneuil. A. A. Popova. (*Doklady A.N.*, 1958, **121**, (3), 453–454).

Low-Frequency Rotational Hysteresis Losses in Ferrites. H. Seiwatz. (*J. Appl. Phys.*, 1958, **29**, June, 994–995).

Considerations on Sintering. An Example of Application: Cutting Tools of Sintered Alumina. L. Gion. (*Silicates Ind.*, 1958, **22**, June, 327–332). Sintered Al_2O_3 tools possess excellent properties due to (*a*) the absence of corrosion at the point of working, (*b*) no change in mechanical properties with temperature and (c) a higher conductivity than normal ceramics.—A. G.

Investigations of Plastic Deformations of Sintered Carbides. E. Bryjak, S. Piaskowski and Z. Bojarski. (*Hutnik*, 1958, **25**, (7–8), 295–303). [In Polish]. Tests were carried out on specimens of sintered carbides containing 3, 6, 11, 15, 20 and 25%Co and tungsten carbide. Cylindrical specimens of 6 to 50 mm dia., mainly 28–30 mm, were used. They were subjected to bending and hardness tests, (Vickers), metallographic examination, etching with Na OH + $K_3Fe(CN)_6$ at magnifications up to × 1400, and X-ray examination. The authors come to the conclusion that plastic deformations do occur in sintered carbides containing less than 10%Co. In order to investigate the mechanism of deformation, further research is needed.

PROPERTIES AND TESTS

Methods of Testing. A.S.T.M. Committee E-I. (*A.S.T.M. preprint*, 1958, (58), pp. 39). Tentatives of metallurgical interest are one for the determination of Poisson's Ratio at room temperature for structural materials with negligible creep, for terms relating to methods of mechanical testing, and for hardness conversion tables for metals.

Supplementary Interpretation of the Images Obtained in Microfractography. J. Plateau, G. Henry and C. Crussard. (*Mét. Corr. Ind.*, 1958, Apr., 141–162). Recent results obtained by microfractography, particularly by the use of the electron microscope and with stereoscopic techniques are discussed. The mechanisms of brittle, ductile and intergranular fracture are dealt with.

A New Roughness Meter. E. Fukushima. (*Métaux-Corrosion-Indust.*, 1958, **33**, Mar., 125–132). Details are given of a new meter for measuring the roughness of surfaces. The instrument is based on the reflection of a light beam from the surface on to a photoelectric cell. It is portable and unaffected by vibration. The calibration of the instrument is discussed.

Microscopical Interference Investigations on Polished Metal Surfaces. E. Raub. (*Werkstattstechn. Maschinenbau*, 1958, **48**, Jan., 37–40). Methods of assessing the quality of surfaces polished by various techniques by means of the study of interference patterns are described. Most of the examples are non-ferrous.—L. D. H.

The Resistance of Cast Steel to Cracks, and Methods for Improving it. N. S. Kreshchanovskii and M. P. Demin. (*Lit. Proizv.*, 1958, (7), 17–21). In all cases, heat cracks, where they appear, do so preferentially along the crystal boundaries and one of the main factors determining the resistance of steel to cracking is the nature of its intercrystalline bonds. This depends on the proportion of alloy elements and on their surface activity.—L. H.

Investigations of the Temperature Dependence of the Modulus of Elasticity of the Iron–Chromium–Sigma Phase. K. Bungardt and W. Spyra. (*Archiv. Eisenh.*, 1958, **29**, Aug., 471–477). Measurements of the modulus of elasticity, resistance and thermal expansion of two Fe–Cr alloys containing 45 and 41%Cr

were made, and the results compared with the properties of an Fe–V alloy with 27%V and an Fe–Ni alloy containing 74%Ni. The fall of the modulus with a drop in temperature, and its accelerated rise on reheating, indicated changes within the σ-phase, the cause of which was examined. It is suggested that Fe–Cr alloys already in solid solution tend to precipitate; the effect of residual stresses within the phase are also discussed.

The Mutual Reaction between the Hardness and Modulus of Elasticity of Pure Metals at High Temperatures. M. G. Losinski and S. G. Fedotow. (*Neue Hütte*, 1958, **3**, Aug., 489–494). The relationship between the hardness and modulus of elasticity of a number of pure metals was investigated over a wide temperature range. In the case of iron it was found that the modulus commenced to fall rapidly between 450 and 500° C, the fall in hardness in this region being even more pronounced. On heating above the Curie point (768° C) the Vickers hardness falls to a minimum value of 5 to 7 kg/mm², and the modulus of elasticity also becomes very small. Both quantities increase suddenly at the transformation point. The hardness is greater at 1000° than at 850° C.

Elastic Anisotropy of Transformer Sheet with "Goss" Texture Having Cube Edges in the Direction of Rolling. F. Stangler. (*Z. Metallkunde*, 1958, **49**, Sept., 489–490). Studies have been made of the modulus of elasticity on Si–iron sheet of various textures as a function of direction.—L. J. L.

Observation of the Sound Waves Arising during the Plastic Deformation of Metals, in Relation to the Problem of the Brittle Fracture of Mild Steel. J. B. Lean and J. Plateau. (*IRSID, Communication aux Journees d' Automne*, 1958, Sept., pp. 10). The formation of Piobert-Lüders bands in mild steel permits of rapid elongation accompanied by sound waves; conversely, the observation of analogous sound waves indicates that sub-critical Piobert-Lüders bands are formed before the upper elastic limit. It is shown that such bands are often formed before brittle fracture; the results are discussed.

The Removal of Hydrogen by Diffusion from Large Masses of Steel. J. D. Hobson. (*JISI*, 1959, **191**, Apr., 342–352). [This Issue].

Anomalies in Tensile and Ductile Properties in the Inter-Critical Range. A. G. Vasil'eva and G. I. Pogodin-Alekseev. (*Metallov. Obra. Met.*, 1957, (1), 23–29). The question as to why the two-phase state in the sub-critical range (ferrite + cementite) does not cause deviation from the regular increase in ductility when the difference in ductility between ferrite and cementite is greater than that between ferrite and austenite is a logical one in view of present theories regarding anomalies in ductility. The structural state in the inter-critical range favours plastic deformation more than the structure in the sub-critical range. The effect of temperature in the inter-critical range on tensile and ductile properties is investigated.—R. S.

The Use of a Dividing Grating in Investigating the Influence of the Stress Conditions on the Elastic Limit of Steel. I. A. Rozov and E. M. Shevandin. (*Zavods. Lab.*, 1958, (3), 317–324). This experimental stress analysis of specially prepared notched specimens on which a grating was milled on the test surfaces, established the fact that before the formation of the first cracks, a particular wavy contour appeared, which corresponded to a concentration of microdeformation of separate grains or of a group of grains.—L. H.

High-Temperature Strain Gauges. (*N.B.S. Tech. Bull.*, 1958, **42**, July, 134–137). Ceramic-bonded gauges for use up to 800° F are described and work in progress to extend working ranges up to 1000° F or even higher is reviewed. A section on testing is included.

Calibration of Mirror Extensometers by Optical Interferometry. A. F. C. Brown. (*Engineering*, 1958, **186**, Aug. 8, 180–182). Work at the N.P.L. is described.

Rating the Ductility of Low Carbon and Alloy Steels by Hot Pressing Tests. I. A. Andreev, I. T. Baruzdin and L. Ya Gluskin. (*Zavods. Lab.*, 1958, (7), 855–858). Tests are described on specimens of various types of steel heated to forging temperatures and pressed under a 700 t forging press, from the parameters of which the compression stress can be calculated. The resulting defects, fissures, cracks etc. are related to the temperatures, composition, etc.—L. H.

Buckling Strength of Type 301 Stainless Steel Plates and Columns. R. E. Peterson and A. O. Bergholm. (*A.I.S.I. Preprint*, 1958, pp. 45). The authors consider the relationship between the mechanical properties of cold-rolled A.I.S.I. Type 301 stainless steel sheet material, and the compressive properties of structural members and elements made from it. New information on the buckling strength of Type 301 cold-rolled stainless steel columns and flat plates is derived from loading tests, and the results are compared with existing theories.—G. F.

The Static and Dynamic Strength of a Carbon Steel at Low Temperatures. C. J. Maiden and J. D. Campbell. (*Phil. Mag.*, 1958, **3**, Aug., 872–885). Compression tests between 15° C and − 121° C are described and the stress-strain curves are compared with those obtained at normal rates of strain between 15° and −183° C. The effect of increasing the strain rate is the equivalent of lowering the test temperature. Slip in ferrite at low temperatures is finer than at room temperature.

The Fine-Grained Structure and Its Influence on the Impact Strength of Welded Seams. B. S. Kasatkin, N. L. Kareta and G. F. Darovskii. (*Avtom. Svarka*, 1958, (2), 20–29). The conditions of the welding greatly influence the properties of the fine-grained structure of low-carbon and low-alloy welded seams. An increase in the cooling rate causes increase in stresses of the 2nd and 3rd orders, a reduction in the size of the grains and a disturbance of the uniformity, whilst a slow rate of cooling favours the formation of blocks of ferritic grains of normal structure. The internal stresses of the 2nd and 3rd order play the greatest role in the process of plastic deformation.—L. H.

Determination of the Toughness of Steel at Low Temperatures. L. S. Livshits and A. S. Rakhmanov. (*Zavods. Lab.*, 1958, **24** (5), 622–625). The author describes a method based on an idea of G. I. Pogodin-Alekseev, in which toughness is determined using standard notched test-pieces and a pendulum impact-testing machine, the energy of impact being progressively increased. The specimens used consisted of type MSt 3 steel, normalized. Tests were carried out at − 20°, − 40°, − 50°, − 60°, − 75° and − 196° C and the energy required for the various stages up to fracture are tabulated and discussed. The method is said to give approximate values for the fracture of a test-piece and an objective indication of the safe service-temperature range of a steel as well as showing low-temperature toughness properties.—S. K.

Method of Measuring the Rate of Plastic Flow of Steel in Explosive Stretching. E. G. Dolmatov and I. I. Sitnikov. (*Zavods. Lab.*, 1958, **24**, (5), 629–631). In the method described the explosion of a 1–2 g. gunpowder charge is used to provide a dynamic load to a tensile test piece, the elongation being followed with the aid of a high-speed cine-camera (4000 frames/sec). The nature of the deformation was found to differ from that obtained in ordinary static tensile testing; in explosive elongation a greater volume of metal is deformed and the plastic flow may be assumed to occur as a wave process; the elongation-time curve shows four zones with different speeds of deformation.—S. K.

The Modes of Deformation Leading to the Fracture of Metals: A Review of Progress to January, 1957. R. Doldon. (*U.K. Atomic Energy Authority* Industrial Group. *IGR-TN/C*-569, 1957, pp. 10). A review of previous work and a report on studies on Al.

Strain Hardening, Softening and High-temperature Strength of Austenitic Alloy Steels. L. A. Metashop and M. E. Blanter. (*Metallov. Obra. Met.*, 1958, (4), 7–9). Steel EI 481 was strain-hardened by 18% elongation of specimens of 3·5 mm dia. Softening was brought about by salt bath heating for 15 min at 450–800° C. Softening began at 550° and was completed at 750°. Creep tests for 25 h on undeformed and elongated steel were made and the breaking strength was also determined, the strained specimens being higher. The effects of Cr, Ni, Co and Mo on 1·2%C–12%Mn steel were also examined. Ni lowers softening temperature and Co has no effect. Cr raises the temperature. Mo lowers it with 0·25–0·5% addition and raises it 100–700° C with 1%.

Investigation of Residual Stresses in High Strength Cast Iron. N. I. Khokhev and G. S. Strizhov. (*Metallov. Obra. Met.*, 1957, (1), 50–56). High strength iron containing nodular graphite exhibits a more marked tendency to the formation of residual stresses than grey iron because of its higher modulus of elasticity and lesser heat conductivity. The distribution of residual stresses throughout the casting is similar in high strength and grey irons with compression stresses at the surface and tensile stresses in the core. Heat treatment for 1 to 1½ h at 600° C or 3 to 5 h at 550° C is recommended for stress relieving.—R. S.

On the Fatigue Limit of Metals. P. Feltham. (*Phil. Mag.*, 1958, **3**, Aug., 806–816). The ratio of the fatigue limit to the critical tensile stress below which slip bands do not appear to form should be independent of temperature. Measurements are made to test this, and within their limits are in agreement with the hypothesis.

Studies of Fatigued Railway Rails. Part II. Measure of Rail Fatigue and Estimation of Rail Life. I. Konishi, M. Kawamoto, M. Naruoka, H. Miki, M. Adachi, B. Kondo, J. Takamura, Y. Niwa and H. Goto. (*Tech. Rep. Eng. Res. Inst. Kyoto Univ.*, 1958, **8**, Feb., 3–34). Fatigue was measured in rails in service and in model tests and attempts to predict service life were made. As the only method of measuring degree of fatigue is to discover the defects produced as early as possible an ultrasonic method of inspection has been developed.

The Causes of Increased Susceptibility of Steel NL-2 to Stress Concentration in Repeated Loading. A. A. Bat'. (*Avtom. Svarka*, 1957, (6), 71–73). Steel NL-2 of chem. composition 0·21–0·18C; 0·3–0·5Si; 0·5–0·8Mn; 0·5–0·8Cr; 0·3–0·7Ni 0·3–0·5Cu; S not over 0·045; P not more than 0·04% was used in a comparison between low-carbon and low-alloy steels in respect of their tendency to plastic deformation and it was found that the low-alloy steel has a higher yield point and therefore that these steels have a smaller tendency to plastic deformation and a greater susceptibility to stress concentrations during repeated loading. This is confirmed by experience.—L. H.

Creep Under Changing Complex Stress Systems. A. E. Johnson, J. Henderson and V. Mathur. (*Engineer*, 1958, **206**, Aug. 8, 209–216; Aug. 15, 251–257; Aug. 22, 287–291). A steel with 0·2%C at 450° C and non-ferrous metals were tested and the findings compared with the various creep theories. The various equations for creep are also plotted and over a wide range agreement is fairly good. The modified Prager equations are discussed and the findings are generalized.

Effect of Composition on the Elevated Temperature Properties of Ductile Iron. R. D. Schelleng and J. T. Eash. (*International Nickel Co. pamphlet*, 1957, pp. 8). Effects of P, Cu and Mo and of heat treatment on creep resistance of ferritic and pearlitic iron at 800° F are examined. ~0·09%P is shown to improve creep resistance, as does Mn but the effect of Cu, except in presence of Ni is adverse.

Experimental Study on the Relationship between Creep Rate-Determining Factors of Low Carbon Steel. T. Nishihara, S. Taira, K. Tanaka and M. Ohnami. (*Tech. Rep. Eng. Res. Inst. Kyoto Univ.*, 1958, **8**, Feb., 35–57). Empirical formulae for primary stage creep are advanced and a "master creep

curve " for graphical representation is developed. The second stage of creep is treated in a similar fashion and the strain rate is related to that in the primary stage so that the properties of both stages of creep can be shown by a common master creep curve.

Method of Measuring Long-Term Hardness on a Rockwell Machine for Evaluating the Creep of Materials. Ya. E. Afanas'ev and A. I. Kolpashnikov. (*Zavods. Lab.*, 1958, **24**, (5), 627–629). In the method proposed by the authors, a Rockwell machine is fitted with a special furnace in which the specimen is placed and the depth of the indentation is determined with the indicator with an accuracy of 0·005 mm, 1, 2, 5 and 10 minutes after the first reading. The application of the method to a non-ferrous alloy is described.

Micro-Hardness Testing. R. Wall. (*Atomics Nucl. Eng.*, 1958, **9**, Jan., 22–23). A report of a lecture.

The Effect of High-Temperature Ageing on the Structure and Properties of 18%Cr, 8%Ni Steels. Kh. I. Cheskis and S. I. Vol'fson. (*Metallov. Obra. Met.*, 1958, (4), 16–25). Service failures in tubes were investigated by a study of the effects of holding 18–8 steels for long periods at 500–900° C. The rate of breakdown was found to depend upon the phases produced and C content. With low (0·07%) carbon, α-phase and carbides form only at grain boundaries. With 0·18%C precipitation of carbides occurred throughout the steel. Some diffusion of Cr also occurred and partial conversion to γ-phase. Impact strength and ductility are reduced, especially in the presence of Ti and Nb.

The Part Played by Microstructure in the Physical Nature of Brittleness. I. E. Kontorovich and B. M. Voshedchenko. (*Metallov. Obra. Met.*, 1957, (1), 35–37). When quenched steel is cooled slowly after tempering at high temperature, there is a further precipitation of dispersed carbides, nitrides, etc. both at the austenite grain boundaries and at the boundaries of the true grain. It is essential to make a separate study of the factors affecting resistance to rupture at the austenite and true grain boundaries.—R. S.

The Effect of Alloying on Temper Brittleness of CrMnNi Steel. M. P. Braun. (*Metallov. Obra. Met.*, 1957, (1), 38–41). Additions of Mo, W and sometimes of V or Al effectively lower the tendency to temper brittleness in CrMnNi steels. Optimum additions are W + V and W + V + Ti.—R. S.

Some Experiments on the Embrittlement of Malleable Cast Iron (Rept. II). N. Tsutsumi. (*Waseda Univ. Rep. Castings Res. Lab.*, 1957, (81, 17–26). Short and long time holding of samples of malleable cast iron in the temperature range 450–550° C produced brittle fracture, the phenomena of embrittlement being reproducible. The results of Charpy impact tests, corrosion tests, electron diffraction patterns and microscopical examination of ductile and brittle specimens are described and compared. The influence of phosphorus content is discussed.

Fracture of Temper Brittle Steel. L. D. Jaffe and D. C. Buffum. (*Trans. Met. Soc. A.I.M.M.E.*, 1958, **212**, Feb., 73–74). From examination of specimens broken under such conditions that the fracture is brittle, the authors show that " upper-nose " temper brittleness can be distinguished from " lower-nose " temper brittleness by visual inspection of the fractured surfaces.—G. F.

Theory of Brittle Fracture in Steel and Similar Metals. A. H. Cottrell. (*Trans. Met. Soc. A.I.M.M.E.*, 1958, **212**, Apr., 192–203). In reviewing the theory of brittle fracture, the author first examines the process of plastic yielding and discusses the nucleation of cracks by slip. He then considers the ductile-brittle transition in un-notched tensile specimens, and the effect of introducing a notch. Finally, the subject of long cracks and service failures is discussed. (73 references).—G. F.

Hydrogen Embrittlement Put on the Spot. A. R. Booker. (*Met. Treating*, 1958, **9**, Mar.-Apr., 10–11). A chart of relief procedures is given.

Method of Testing for High-Temperature Wear. M. P. Markovets and V. P. Tret'yakov, (*Zavods. Lab.*, 1958, **24**, (5), 625–626). The authors briefly describe their method and equipment for the wear testing of tool steels at 20–800° C and tabulate results obtained for specimens of type 5KhNV, 3Kh2V8 and EI617 steels with and without lubrication. Wear is produced by 3000 revolutions of a roller under a load of 3 kg.—S. K.

Wear Resistance of Magnesium Cast Iron with Different Metal Bases. A. D. Ushakov. (*Lit. Proizv.*, 1958, (5), 17–18). In the investigation described the wear of test pieces of Mg inoculated iron (3·1–3·35%C, 2·25–2·38%Si, 0·9–1·0%Mn, 0·052–0·055%P, 0·009–0·014%S, 0·04–0·058%Mg) with various structures was measured. The wear was effected by contact with a lubricated hardened-steel roller surface. Before testing, pieces were subjected to neutron-irradiation to produce some ^{59}Fe and the wear was measured from a comparison of the activity of the used lubricant and that of the test piece. The structures tested were normalized pearlitic, isothermally hardened with a troostite-sorbite base, with a granular pearlite structure and ferritic-cementite and these were found to have different resistances to wear.—S. K.

Wear-Resisting Small Cast Iron Parts. O. A. Nesvizhskii. (*Lit. Proiz.*, 1958, (1), 5–6). Lengthy laboratory investigations and trials under normal industrial conditions have resulted in the elaboration of a chemical composition for the metal and a technological process for the manufacture of small balls and cylinders which have proved most reliable in use.—L. H.

A New Method of Measuring the Temperature of the Friction Surface Between Different Metals. A. S. Vagramyan. (*Vestnik Mashin.*, 1958, (7), 13–15). A support with a special adaptor is described, on which different metals can be rotated under pressure, and the heat generated is then related to formulae specially derived for the pressure and speed of rotation for each separate metal.—L. H.

Concentrated Wear of Turning Tools. V. Solaja and D. R. Cliffe. (*Met. Treatment*, 1958, **25**, May, 187–190). Grooves developing on carbide-tipped tools were examined and explanations previously advanced are discussed in the light of new investigations.

The Wiedemann Effect of the Binary System of Iron–Aluminium Alloys at High Temperatures. Y. Shirakawa, T. Ohara and T. Abe. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1958, **10A**, June, 212–218). Also in *Nippon Kinzoku*, 1956, Feb.

The Preparation of Colloidal Solutions of Magnetite for the Study of Domain Structures in Ferromagnetic Materials. J. Hejduk. (*Chem. Listy*, 1958, **52**, (7), 1350–1352). [In Czech]. A method for the production of colloidal solutions of magnetite with reproducible properties is described. The method is based on washing the hydrated ferroso–ferric oxide with distilled water (pH = 5·3), followed by the stabilization of the colloidal solution with a protective colloid prepared by the neutralization of olein with NaOH.

A Comparison of Results Obtained for Impact Tests with Different Test Bars. G. Mayer and L. H. Toft. (*Rev. Nickel*, 1956, **22**, Oct-Nov-Dec., 87–92). The authors discuss results obtained with different impact test bars and give mathematical relationships, obtained experimentally, for converting and comparing results.—R. F.

Kinematic Aspect of Fracture Patterns. J. Leeuwerik. (*Métaux Corr. Ind.*, 1957, **32**, Nov., 443–457). It is shown that geometrical patterns formed on a fractured surface can appear very similar in different materials. These patterns are related to the speeds of propagation of primary and secondary wavefronts which are set up as the fracture develops and the relations of these speeds can be calculated from the geometry of the patterns. The mechanism of fracture is discussed in detail.—L. D. H.

Impact Strength of Spheroidal-Graphite Iron as Influenced by Temperature. A. B. Everest. (*Found. Trade J.*, 1958, **104**, June 26, 779–782). Composition, structure and the conditions required to develop high impact strength are reviewed. Uses are considered.

Contribution to the Assessment of the Notched Bar Toughness of Pit Support Members made from Steel. W. Schaefer. (*Glückauf*, 1958, **94**, Feb. 1, 176–179). Investigation showed that the notched bar toughness of test pieces, after ageing, should increase with the tensile strength of the steel. The toughness, measured in kg/cm², should not be less than 3·2% of the tensile strength in Kg/mm². It is pointed out that this figure is only a general guide.—L. D. H.

Low Temperature Burst Tests of Flash-Welded Line Pipe. M. A. Scheil, G. E. Fratcher, S. L. Henry and E. H. Uecker. (*Eng. J.*, 1958, **41**, Mar., 64–71). Tests were carried out down to −50° F on X52 grade pipe. The ductility was the same as at ordinary temperatures. Comparison with Charpy V-notch tests showed little correlation.

Strain Hardening of Austenitic Stainless Steel. G. W. Powell, E. R. Marshall and W. A. Backofen. (*Trans. A. S. M.*, 1957, **50**, Preprint 10, pp. 40). The stress-strain relationship of types 301 and 304 steels is dependent on the stability of austenite with respect to transformation. At − 263° C, the tensile deformation is shown by discontinuous yielding and multiple necking. Suggestions are made to explain the effects.—E. E. W.

Photo-elastic Investigation of Stresses in the Heads of Thick Pressure-Vessels. H. Fessler and R. T. Rose. (*Proc. I.M.E.*, 1957, **171**, (20), 633–646). The use of the frozen stress technique is described.

Stress Cracks and their Origins in Cast Iron. H. T. Angus and W. G. Tonks. (*Giesserei*, 1958, **45**, Feb. 13, 81–86). The influence is discussed of such factors as design, iron composition and structure on the incidence of stresses in castings. Reference is made to a number of examples, and measures for reducing the stresses produced are indicated.

Elevated Temperature Relaxation Properties of 17–7 PH Stainless Steel Helical Compression Springs. M. Clogg, jun. (*Wire Wire Prod.*, 1958, **33**, Apr., 401–405). An investigation into the relaxation properties at temperatures up to 750° F of the above named material is reported, the data being compared with those for 18 Cr–8 Ni, Inconel 'X', and music wire springs. In particular, results are quoted on the effects of hardening temperature, stress-relieving temperature testing temperature and time on relaxation, and also the effect of temperature on torsional modulus.—J. G. W.

A New Rotating Cantilever Machine for Fatigue Tests at High Temperature. G. Vidal. (*Rev. Mét.*, 1957, 54, Dec., 971–978). A detailed description of this machine for hot fatigue tests in rotary flexion is given; small stresses on small specimens can be applied. An automatic device for obtaining partial rupture of the specimen enables specimens to be obtained without damage which can later be examined under good conditions. Results on copper, a cermet and a Nimonic alloy are given. Micrographs of fatigue cracks on the Nimonic alloy at 800° C are reproduced.—B. G. B.

Torsion Fatigue Tests. (*Engineering*, 1958, **185**, June 20, 786–787). A high speed machine developed by Alfred J. Amsler & Co., Schaffhausen, is described. The device is known as the Torsator and is derived from the Vibrophore, making use of an electromagnetic oscillator and recording by drum camera. 10^7 cycles take 14 h.

Dynamic Calibration of Fatigue-Testing Machines. T. M. Dowell. (*Engineering*, 1958, **185**, May 30, 693–696). An electrical resistance strain-gauge method for calibrating direct stress testing machines is described.

The Delayed Failure of Hardened Steels. A. L. Nemchinskii. (*Fiz. Met. Metalloved.*, 1957, **5**, (1), 110–112). The presence, in the graph of the delayed failure of hardened steels, of two sections, one inclined and the other horizontal, can be explained by the fact that their failure is determined by various conditions; the inclined segment represents the thermodynamical conditions leading to

failure, and the horizontal segment, the activation conditions. The coincidence of the minimum levels of strength during the growth of the longitudinal fissures depending on different causes (longitudinal stressing and repeated hardening) offers experimental confirmation of this point of view.—L. B.

'Size' Effects and their Possible Significance for 'Non-Propagating' Cracks in Metal Fatigue. W. J. Harris. (*Metallurgia*, 1958, **57**, April, 193–197). For the case of the fatigue strength of metals and the existence of non-propagating fatigue cracks it is suggested that the fundamental rôle of 'size phenomena' is attributable to the existence of characteristic 'flaw patterns'.—A. G.

Hull Cracks in Destroyers. W. M. M. Fowden, jun. and H. Q. Mar. (*J. Am. Soc. Naval Eng.*, 1958, **70**, May, 349–353). Various fatigue cracks, mostly below the waterline, appearing in destroyers are described.

Some Metallurgical Aspects of the Blade Fatigue Problem in Aircraft Gas Turbines. K. B. Young. (*Canad. Min. Met. Bull.*, 1958, **51**, May, 279–287). Analysis of failures and the effects of heat treatment on fatigue strength are considered. Inconel and Nimonic alloys are mainly discussed.

A Modern Method of Controlling and Testing Chains: Fatigue Test. J. R. Strebelle. (*PACT*, 1957, **11**, Oct., 431–433). The author discusses results obtained when applying fatigue tests to the production control of chains and particularly to judging the strength of different types of welds.—R. P.

The Effect of Per Cent Tempered Martensite on Endurance Limit. F. Borik, R. D. Chapman and W. E. Jominy. (*Trans. A. S. M.*, 1957, **50**, *Preprin*, 16, pp. 24). The endurance limits of a number of steels were approximately the same for a given amount of martensite when tempered to a given hardness irrespective of their hardenability. Small percentages of non-martensitic structure have a deleterious effect on the fatigue strength of the steels tested.—E. E. W.

The Influence of Temperature, Rate, and Degree of Deformation on the Resistance to Strain of Carbon Steels. Z. A. Ridner and A. P. Chekmarev. (*Izvest. Akad. Nauk. Otdel. Tekhn.*, 1957, (12), 22–29). The specially built testing machine, on which investigations were made, applied a monoaxial load with a frequency of 2/300 cycles per sec. A full description of the machine and of the experimental procedure is given and results are tabulated in respect of each separate influence investigated, i.e. the rate of application, the temperature, the degree of deformation and the chemical composition. 5 Steels were examined.—L. H.

On the Mechanism of Wear between Metal Surfaces. G. Yoshimoto and T. Tsukizoe. (*Wear*, 1958, **1**, June, 472–490). A simple model is evaluated for real area of contact and mechanical wear and Fe_2O_3 and Fe_3O_4 film wear processes are considered theoretically alone and acting in combination.

The Effect of the Nature of the Porosity of Chromium Plate on the Wear of Cast Iron. D. N. Garkunov and A. A. Polyakov. (*Centre d'Information du Chrome Dur, Bull. Doc.*, 1958, Jan., 15–24; from *Inst. Mash. Ved. Sbor. U.S.S.R.*, 1956, **11**, 108). [In French]. A wear testing machine is described and results related to degrees of porosity are shown. The work was done on pistons working in cast iron cylinders.

A Study of the Phenomenon of Wear and Its Prevention by Electric Welding. V. Vilhalm. (*Universidad de la Plata, Special Publications*, **49**, *Third Series*, No. 214, 1956, Dec., pp. 67). [In Spanish]. After a discussion of the mechanics of friction and wear, the author gives the standard classifications of the wear-resistant materials and discusses these by reference to composition, microstructure and type of wear resistance required. It is pointed out that usually only the outer layers of the part need special protection and such a coating can usually be achieved by welding, a method deserving greater attention from machine makers. There is no universal material, the best choice to suit the working conditions must be made in each case. Detailed attention is given to Hadfield's manganese steel and its advantages and disadvantages, and applications are discussed, as also are the effects of nickel additions. (27 references).—P. S.

Penetrant Methods of Inspection. R. Schnurmann. (*Research*, 1956, **11**, July, 254–257). A brief review.

Magnetic Properties. A.S.T.M. Committee A-6. (*A.S.T.M. preprint*, 1958, No. 4, pp. 58). Proposed standard methods of test are given for laminated core and Epstein specimens, A.C. magnetic properties.

Magnetic Properties of Solid Solutions of Ilmenite and Haematite. Y. Ishikawa. (*Metal Physics*, 1957, **3**, Mar., 81–82). [In Japanese].

Behaviour of the Magnetic Properties and Mechanical Hardness in the Precipitation-Hardening Fe–Mo Alloys. Y. Kimura and R. R. Hasiguti. (*Metal Physics*, 1956, **2**, Jan., 27–28). [In Japanese].

Direct Measurement of the Velocity of Propagation of a Ferromagnetic Domain Boundary in "Perminvar." E. W. Lee and D. R. Callaby. (*Nature*, 1958, **182**, July 26, 254–255). A method making use of the Kerr effect was used.

On the Effect of Silicon on the Magnetic Properties of Precipitation Magnetic Alloys of Fe–Ni–Al System. S. Koshiba and T. Nishinuma. (*Nippon Kinzoku*, 1957, **21**, Mar., 166–169). [In Japanese]. Experiments were made on Fe–Ni–Al alloy, Fe–Ni–Al–Co–Cu alloy, anisotropic Fe–Ni–Al–Co–Cu alloy. The coercive force decreases as Si content increases and the residual induction increases for the magnetic alloys having non-magnetic field treatment. With anisotropic Fe–Ni–Al–Co–Cu and Fe–Ni–Al–Co–Cu–Ti alloys, residual induction increases as Si content increases to about 1%, but then decreases markedly. (11 references).—K. E. J.

The Initial Magnetization of α-Iron at High Temperatures. L. Alberts and B. J. Shepstone. (*Phil. Mag.*, 1958, **3**, July, 700–706).

Energy Levels of Iron Group Ions in Paramagnetic Salts. K. Kambe. (*Metal Physics*, 1956, **2**, Sept., 182–190). [In Japanese].

Ultrasonic Testing of Welds. W. H. Papke. (*Schweissen Schneiden*, 1958, **10**, April, 131–135). The ultrasonic test method applied to welds is described, and the most important defects which occur and their interpretation are discussed. Examples are given.—U. E.

Attenuation of Ultrasonic Waves in Metals. VII. Stainless Steel. T. Hirone and K. Kamigaki. (*Nippon Kinzoku*, 1957, **21**, Apr., 245–248). [In Japanese]. Ultrasonic attenuation coefficients were measured in the range 0·5–6·0 Mc/s for austenitic stainless steel containing 19% Cr and 10% Ni. The coeff. increases sharply with frequency, being mainly explained by Rayleigh scattering of ultrasound by austenite grains. The magnitude of the scattering is largely determined by the degree of elastic anisotropy in the austenite grains.

The Ultrasonic Beam in Immersion Technique. J. Krautkrämer. (*S.S. News*, 1958, June, 7–12; from *Metallkunde*, 1957, Nov.). The process of flaw detection by the immersion method is described, the formulae for pulse frequency and test speed are derived and improvements are suggested.

Nondestructive Testing. A.S.T.M. Committee E-7. (*A.S.T.M. preprint*, 1958, No. 62, pp. 20). **Quality Inspection by Radiographic Testing.** (3–8). **Wet Magnetic Particle Inspection.** (9–20). Two tentative methods are described.

X-Ray Diffraction by Imperfect Crystals. M. A. Jaswon. (*Research*, 1958, **11**, June, 227–235). Martensite and other materials are considered.

Thermal Properties of Thirteen Metals. C. F. Lucks and H. W. Deem. (*A.S.T.M. spec. Tech. Publ. No.* 227, 1958, pp. 29). SAE 1010 steel from − 250° to + 1650° F and types 301, 316 and 347 from − 250° to 1800° F are included.

Properties of Materials at High Temperatures. (*N.B.S. Tech. Bull.*, 1958, **42**, June, 112–119). Among other topics, tests on protective coatings (of ceramics), effects on the mechanical properties of 17-7 PH steel and especially the mechanism of hardening, and on the corrosion of steel by V compounds in petroleum plant, and the attack on steel by slag are discussed.

Effect of Temperature on the Properties of Metals. ASTM–ASME Committee. (*A.S.T.M. preprint*, 1958, (68), pp. 26). **Properties of Cast Iron at Elevated Temperatures.** (5–6). **Short-Time Elevated-Temperature Tension Tests of Metallic Materials.** (7–13). A tentative recommended practice method is given. **Conducting Creep and Time-for-Rupture Tension Tests of Materials.** (15–26). Another tentative method report.

Research into the Strength at Elevated Temperatures and Heat Resistance of Austenitic Cast Steel, Mn–Cr–(Ti) 17/7. K. Löbl and B. Potůček. (*Slevarenství*, 1958, **6**, Apr., 97–105). Owing to the shortage of Ni, Mo and Nb, which have to be imported into Czechoslovakia, mainly from the West, the above steel has been developed on economic grounds. The results of the experiments at normal and elevated temperatures, including creep tests up to about 10,000 h, are fully comparable with those for Cr—Ni steels. At 600–650° C the material has adequate structural stability, especially with regard to the formation of the sigma phase which showed a tendency to diminish by decomposition during prolonged heating, and adequate heat and corrosion and scaling resistance for the purposes for which it was intended, i.e. for bodies and other cast parts of high-pressure steam installations working at temperatures of 625–650° C and 200–300 atm. The article implies that the material can be welded, but no report of tests is given.—M. T.

Heat Resisting Steels and Alloys. P. Villain. (*Mét. Constr. Mécan.*, 1958, **90**, May, 345–358). The mechanism of formation of heat resisting layers on the surface of pure metals, binary and ternary alloys is discussed together with creep resistance and methods for its measurement. Properties of a number of Fe–Cr and Fe–Ni–Cr alloys are considered.

Studies on the Heat Resistant Properties of Nickel Solid Solution Binary Alloys. M. Okamoto and S. Okada. (*Nippon Kinzoku*, 1957, **21**, Sept., 544–548). Data are presented on solid solution hardening, work-hardening, recrystallization, softening temperatures, and oxidation resistance of binary solid solutions of nickel. Generally, the greater the difference in atomic radius between the two elements, the greater the solution hardening; the soften the alloy initially, the greater the work-hardening; the larger the amounts of alloying element, the higher the softening temperature. Iron is among the elements which reduce the oxidation resistance.—J. G. W.

The Diffusion of Carbon in Alloy Steels. W. Seith and F. Bartschat. (*Z. Metallk.*, 1942, **34**, 125–130; translation 19*RI-T/C*–82).

Properties and Applications of Some Nickel–Copper–Chromium Irons. G. Henon. (*Fonderie Belge*, 1958, **28**, Apr., 122–123). The use of copper additions as a partial substitute for nickel in Cu–Ni–Cr irons is discussed. Its graphitizing effect, solubility and influence on mechanical properties are outlined. Applications to martensitic white iron and to martensitic and sorbitic grey irons are mentioned.

The Development of Stainless Steels. R. Pospíšil. (*Hutník*, 1958, **8**, (6), 191–193). The historical development of the production and uses of stainless steels is surveyed, including that of modern Cr–Ni steels used at high temperatures.—P. F.

Ductile Stainless Work Hardens for Extra Strength. (*Iron Age*, 1958, **181**, May 29, 88–89). Properties of a new high strength steel called "MicroMach" are described. It combines strength and ductility especially in the extra-full-hard condition. It is a 17%Cr, 6%Ni type of steel with controlled C and N.

Metallurgical Notes. A. D. Marsico. (*Teen. Indust.*, 1958, **36**, June, 651–652). Notes are included on silicon steels, the effect of low

melting point eutectics on the properties of steel, free-cutting steels and high-aluminium nitriding steels.

Cast Age-Hardening Austenitic Steels. E. A. Lange, N. C. Howells, and A. Bukowski. (*NRL Report* 5140; *PB* 131733–050, 1958, May 5, pp. 14). Cr–Ni–P, Cr–Mn, and Cr–Ni–Mn–V types of age-hardenable austenitic steels were studied for the production of non-magnetic castings. A Cr–Ni–P steel with 0·3%C and 0·25%P developed yield strength at the 10^5 psi level. Cr–Mn steels with P or V were age-hardenable but formed brittle castings when heat-treated. A fourth type, of Mn–V steel, with similar strength values was developed.

High Strength Weldable Steels. K. J. Irvine. (*Metallurgia*, 1958, **58**, July, 13–23). The properties of high strength structural steels high in Mn, and with varying amounts of low alloy additions are discussed, and the structural characteristics favourable to weldability are described. It is shown that a bainitic structure is the most suitable.

Principal Tendencies in the Development of Instrument Steels. Yu. A. Geller. (*Metallov. Obra. Met.*, 1957, (11), 43–56). The article is a general review of what has been accomplished in Soviet Russia during the last 40 years since the revolution, and of what is being done now in the cause of further progress on carbon, alloy, chromium, high-speed and hot-working steels and mentions the various heat treatments appropriate to instrument steels.—L. H.

Research and Development of Heat-Resisting Steels. A. V. Stanyukovich. (*Metallov. Obra. Met.*, 1957, (12), 26–30). The experimental findings from endurance tests have shown the dependence of the limiting duration resistance σ_d on temperature to agree with the equation

$$\sigma_d = Be^{\frac{K}{T}}$$

where T is the absolute temperature and B and K are constants characterizing the material. Since the numerical value of K for intercrystalline failure is practically the same for different steels, it is possible to determine easily the dependence of σ_d on the temperature. On this basis, different qualities of heat resisting steels are investigated and the optimum temperature for their service conditions determined.—L. H.

Medium and Low Tungsten High-Speed Steels Alloyed with Cobalt. M. S. Chaadaeva. (*Metallov. Obra. Met.*, 1958, (3), 48–53). New experimental steels were developed and heat-treatments, retained austenite, hardness, bend strength and the effect of sub-zero treatments, forging properties and results from carbonitriding and sulphidizing including the carbide phase compositions and the effects on cutting tool life are described. The life was three times that of 18–4–1 type steels in the case of 13–5–Cb with 1·5%C, 11·45%W, 4·5%V, 4·1%Cr, 0·9%Mo, 5·7%Co, 0·97%Nb, 0·42% Mn, 0·53%Si, 0·03%S and 0·02%P.

Chromium Aluminium Steels. Properties and Applications. E. Herzog. (*Corros. Anticorros.*, 1958, **6**, May, 162–170). This section deals with the plastic deformation, ageing, corrosion-cracking properties and industrial applications of these alloys.

Creep-Resisting Austenitic Mn–Cr Steel Type 17–7. F. Pobořil, P. Jehlička, J. Majer and M. Zezulova. (*Vyzkumne Práce z Oboru Železa a Oceli*, 1958, 91–117). A substitute steel with some Ti was developed and its structure determined by optical, X-ray and magnetic methods. It consists of austenite and ϵ-phase with small quantities of ferrite and Ti carbide. Below 200° C an $\epsilon \rightleftarrows \gamma$ transformation occurs so that above this the ϵ-phase largely disappears. Scaling resistance in O_2 at 700–800° C for 120 h equals low-alloy ferrite–pearlite steels at 500–550°. Creep characteristics are satisfactory at 550–650°.

Vascojet 1000. J. C. Hamaker jun. (*S.A.E.J.*, 1958, **66**, July, 68–73). The properties of a 5%Cr steel for operation between − 100° F and + 1000° F which hardens fully on air cooling from 1850° F are given. Surface protection by Ni–Cd plating, hot-dip aluminizing and by nitriding treatment is also described. Forging and welding conditions are also given.

Properties of EI 579 Steel. V. G. D'yakov. (*Metallov. Obrabotka Met.*, 1957, (9), 9–16). The results are presented and discussed of a series of tests on specimens of six plant heats of EI 579 steel (0·16–0·22%C, < 0·40% Si, 0·25–0·50%Mn, 2·5–3%Cr, 0·35–0·50% Mo, 0·30–0·50%W, 0·70–0·85%V, < 0·25% Ni, < 0·030%S, < 0·030%P), covering a considerable part of the permissible composition range. The influence of composition on the critical points and on the mechanical properties after various heat treatments was studied as well as the mechanical properties at various temperatures, the tendency to embrittlement on prolonged heating and the long-term strength and creep properties. The steel is recommended for heavily loaded parts working at temperatures up to 550° C inclusive.—S. K.

I.R.S.I.D. Testing Station at Maizières-lès-Metz. (*Mét. Constr. Mécan.*, 1958, **90**, June, 429–441). The recent inauguration of the new I.R.S.I.D. testing station at Maizières-lès-Metz is described, speeches made on this occasion being reported and the installation described.

Visit to the Central Research Institute for Ferrous Metallurgy in Moscow. R. Kraus. (*Giesserei-techn.*, 1958, **4**, July, 194–195). Methods of sampling, chemical analysis, polarographic, spectrographic, metallographic, mechanical and physical testing seen at a visit to the metallurgical Research Institute at Moscow are described.—L. D. H.

METALLOGRAPHY

The Trends in High-Temperature Metallography. M. G. Lozinskii. (*Metallov. Obra. Met.*, 1957, (11), 18–42). The writer reviews the progress made in recent years in this branch of applied science, describes new apparatus already in mass production, and outlines the tendencies towards which the efforts of Soviet investigators are now directed.—L. H.

Micrographic Testing and the Application of Dislocation Theory. J. B. Lean and J. Plateau. (*Mét.-Corr.-Ind.*, 1958, Oct., 389–405). The theory is developed and illustrated with electron micrographs and diagrams. The theory is shown to lead to an explanation of observations and to calculations of the right order while the existence of dislocations is confirmed by the micrographic observations. (85 refs.).

Light-Figure Phenomena Revealed and Crystal Planes Developed by Chemical Etching in Single Crystals of Nickel–Iron Alloys. M. Yamamoto and J. Watanabé. (*Nippon Kinzoku*, 1956, **20**, Sept., 520–524). Distinct light figures are produced in single crystals containing 30–81·5%Ni by several etchants, the best being boiling saturated aq. $FeCl_3$. Etching develops the most closely packed {111} faces, their vicinal faces, and high-index crystal faces inclined 10–15° to {100} and {110} planes.—K. E. J.

Effect of Heat-Treatment on the Precipitation of Aluminium Nitride and on the Mechanical Properties of Plain Steels. P. Werthebach and H. Hoff. (*Stahl Eisen*, 1958, **78**, May 29, 736–743). The authors studied the effect of rolling temperature, cooling rate and heat-treatment on the combination of N_2 with Al in various steels of different N and Al contents.

Growth Pattern on the Surface of Fe_3O_4 Solidified from the Melt. N. Miyata and Y. Gondo. (*Metal Physics*, 1955, **1**, Sept., 202). [In Japanese].

The Cube Texture of Iron–Silicon Alloys Obtained by Recrystallisation. H. E. Möbius, and F. Pawlek. (*Arch. Eisenhütt.*, 1958, **29**, July, 423–432). Pole-figure determinations and torque measurements were carried out on silicon iron in a study of the effect of silicon content on recrystallization behaviour. The cube texture is promoted by limiting the Si content to 1·8–2·2%. Pole-figure determination of the cube texture during recrystallization annealing showed that the primary recrystallization texture is obtained from the dispersed rolling texture (112) [110] via two intermediate stages: the Goss texture and the cube texture (100) [001]. The latter grows at the expense of the former, this being more pronounced with increasing temperature. The effects involved are discussed theoretically.—T. G.

Recrystallisation Textures of Cold Rolled Transformer Sheet Steel. H. Stäblein and H. Möller. (*Arch. Eisenhütt.*, 1958, **29**, July, 433–447). Transformer sheet steel containing 2·65% silicon and 0·052 or 0·011% carbon was used for a study of the recrystallization textures after various degrees of working and annealing treatments between 500 and 1300° C. X-Ray sharpness of the primary textures becomes more pronounced with increasing degrees of working. The Goss orientation [100](011) important for grain-oriented transformer sheet appears in texture-free polycrystalline material after about 50% rolling as secondary recrystallization, it is not found for high degrees of working, e.g. 92%. Carbon impedes secondary recrystallization and the formation of the Goss texture. The various theories on these phenomena are discussed. (39 references).—T. G.

Dilute Solutions in Molten Metals and Alloys. C. B. Alcock and F. D. Richardson. (*Acta Met.*, 1958, **6**, June, 385–395). [In English]. Measurements of the activity coefficients of sulphur in molten copper and binary alloys with iron and other metals at 1100°–1500° C, show that the thermodynamic properties of the dissolved S cannot be explained on the basis of electron chemical potential or on the corresponding electron: atom ratio. A theory having a chemical basis is developed which leads to relations between the activity coefficients of sulphur in elementary metals and the stabilities of the sulphides. The behaviour of solutes in dilute solution in ternary alloys can be forecast from the energies of interaction of the simple binary systems.

The Effect of Boron on the Nucleation and Growth of Pearlite. Lee Ling, Chi Min-wei, Chung Ching-chi and Meo Yang-tze. (*Acta Met. Sin.*, 1957, **2**, (1), 59–68). [In Chinese]. In both hypo-eutectoid and eutectoid steels, boron increased the incubation period for pearlite formation at the temp. of maximum formation, but did not affect the nucleation rate. This is attributed to increase of stability of austenite by reduction of the grain-boundary energy. The actual growth rate of pearlite is increased by boron.—K. E. J.

On the Graphitization of High Carbon Tool Steels. Ho Zhung-zhe, Sun Wen-chuang and Ko Tsun (T. Ko). (*Acta Met. Sin.*, 1956, **I**, (2), 279–287). [In Chinese]. Various effects of heat-treatment and hot-working on graphite formation in 1·1–1·2% C tool steels during subsequent annealing are reported and explained. (13 references).

The Formation of Graphite in Annealing in Steels and White Irons. J. Pomey, R. Lafont and L. Abel. (*Compt. Rend.*, 1958, **246**, Feb. 17, 1044–1045). Each martensite platelet gives rise, on tempering and annealing, to a crystalline flake of graphite. Martensite gives rise to ϵ-carbide and this forms graphite. The energy of activation for graphite growth is about the same as that for autodiffusion in both α- and γ-states.

The Decomposition of δ-Ferrite in a Cr–Ni–Mo–Ti Stainless Steel. Chuang Yu-chih and Liu Chia-lo. (*Acta Met. Sin.*, 1956, **1**, (4), 337–346). [In Chinese]. The decomposition at 750°, 850° and 950° C was studied by microscopical and X-ray diffraction methods, for quenched 18 : 8 : 3 : 1 Cr–Ni–Mo–Ti steel. At the early stages acicular austenite forms; the remaining ferrite becomes enriched in Cr and Mo and impoverished in C, Ni and Mn, transforming later to sigma. Pptn. of TiC occurs first in the ferrite and then in interphase boundaries etc. The impact value decreases markedly before the $\delta \rightarrow \sigma$ transformation. (15 references).—K. E. J.

On the Continuous Cooling Transformation Diagram of Ball-Bearing Steel. M. Tagaya, I. Tamura and K. Akamatsu. (*Nippon Kinzoku*, 1957, **21**, Mar., 145–149). [In Japanese]. The diagram is presented for

steel containing 0·98% C and 1·40% Cr, using Liedholm's method. It's validity is checked from cooling curves of round bars cooled in different coolants. (16 references).

Stabilization of Austenite in an Iron–Nickel–Manganese Alloy. Shih Chang-hsu. (*Acta Met. Sin.*, 1956, **I**, (3), 289–293). [In Chinese]. (16 references).—K. E. J.

Kinetics of Decomposition of Retained Austenite During Tempering in Some High Strength Steels. Shih Chang-hsu. (*Acta Met. Sin*, 1956, **1**, (4), 383–393). [In Chinese]. Studies were made on AISI 4325, AISI 4340 and the corresponding silicon-modified steels by precise length measurements. In steels with normal silicon content (0·2–0·3%), the activation energy of decomposition of retained austenite is ~35,000 cal/mole, comparable with that of diffusion of carbon in γ-Fe. In high-silicon (1·5% Si) steels, Si retards the transformation. The activation energy is ~44,000 cal/mole. It is suggested that the diffusion of Si in γ-Fe surrounding the growing carbide particles is the rate-controlling factor. (17 references).—K. E. J.

The Effect of Austenitizing Treatment on the Formation of Lower Bainite in a Plain Carbon Steel. L. W. Graham and H. J. Axon. (*JISI*, 1959, **191**, Apr., 361–365). [This Issue].

The Effect of Boron as a Function of Austenitising Temperature. Lee Ling, Yu Shou-lu and Chen Chung-lian. (*Acta Met. Sin.*, 1957, **2**, (1), 69–80). [In Chinese]. The hardenability of boron steel decreases with increasing temp., and depends more on the distribution of free boron atoms in austenite than on the oxygen and nitrogen contents. By direct quenching from high austenitizing temperatures, boron was uniformly distributed within the grains and at the boundaries; in samples slowly cooled, etc., it appeared at the boundaries. The loss of hardenability is thus attributed to desorption of boron atoms near the grain boundaries.—K. E. J.

Studies on Heat-Treatments of High Alloy Tool Steels. II. On the Transformation of Retained Austenite in High-Carbon High-Chromium Steel by Subzero Chilling. T. Nemoto. (*Nippon Kinzoku*, 1957, **21**, Feb., 85–88). [In Japanese]. Investigations were made by means of hardness, electrical and magnetic measurements. Retained austenite is markedly stabilized against transformation by subzero chilling with increase of the holding time at room temp. Retained austenite transforms to martensite by subzero chilling, but during subsequent heating the martensite begins to decompose at a lower temperature than with normal quenching. The amount of retained austenite increases with holding time at the bainite transformation temp. Retained austenite is not completely transformed by subzero chilling in liquid oxygen. (28 references).—K. E. J.

On Isothermal Transformation of Steel below MS Temperatures. S. Owaku and K. Iijima. (*Nippon Kinzoku*, 1957, **21**, Sept., 531–535). From electrical resistivity, microstructure, and dilatation measurements during isothermal transformation and tempering treatments, it was concluded that during treatments below the M_S temperatures the beginning and completion times of the transformation of retained austenite into bainite fitted on to the curves for temperatures above the M_S points suitably extrapolated. The same times were obtained for isothermal tempering. Isothermal transformation below the M_S temperatures resulted in superior toughness, compared with both isothermal tempering and conventional quench-and-temper treatment.—J. G. W.

The Influence of Plastic Deformation on Transformations in Stainless Austenitic Steel. A. P. Gulyaev. (*Hutnik*, 1958, **25**, (7–8), 237–241). [In Polish.] The article is a translation of a lecture delivered by a Russian Prof. Gulyaev in Cracow in May 1958. The plastic deformation in austenitic steels brings about complicated changes in structure, which consist in deformation of the crystalline lattice and phase changes. These changes are not yet fully explained. The author describes the results of his own and his co-workers' investigations. Decomposition of austenite, phase changes $\gamma \rightarrow \alpha_2$, $\alpha_2 \rightarrow \gamma$ and $\gamma \rightarrow \epsilon$ are discussed in steels with high chromium and nickel content (17–20%Cr, 8–11%Ni and 0·45%C, 15–23%Ni). The influence of various parameters, deformation, temperature, and time of stabilizing is given. The problems connected with the less known $\gamma \rightarrow \epsilon$ transformation (sometimes called $\gamma \rightarrow \theta$) are explained. High tensile strength (195 kg/mm²) and the good plastic properties of the steel, 0·45%C, 19%Ni, are emphasized.—S. S.

Techniques of Studying Phase Changes. E. G. Ramachandran and V. Prakash. (*Tisco*, 1958, **5**, Oct., 192–197). Microscopical, thermal, dilatometric, X-ray, magnetic, electrical resistance, damping and internal friction studies, ultrasonics and electron microscopy are briefly considered. (30 refs.).

Property Changes on Phase Transformations —Physical Theory. E. G. Ramachandran. (*Tisco*, 1958, **5**, Oct., 183–191). The electron theory of metals is developed and specific heat, electrical conductivity and magnetic properties are discussed.

A New Phase in a Complex Alloy Steel. G. T. Brown, R. T. Allsop and D. Wilkinson. (*Nature*, 1958, **182**, Nov. 22, 1437). A steel with 12%Cr, 4%Ni, 3% Mn and 2·5%Si while under examination for age-hardening yielded a new phase which was isolated electrolytically. X-Ray spacings are given corresponding to face-centred cubic and composition corresponding approximately to M_3Si where M is largely Ni.

Further Studies of the Iron–Chromium System. R. O. Williams. (*Trans. Met. A.I.M.E.*, 1958, **212**, Aug., 497–502). The Cr-rich portion of the miscibility gap previously proposed for the Fe–Cr system was examined by means of neutron diffraction, electrical resistance and chemical extraction, and the results discussed. (21 refs.).

Studies on Uranium–Iron Alloys. T. Geiger and C. Fizzotti. (*Sulzer Tech. Rev.*, 1958, **40**, (3), 23–29). Tests on the effects on fuel elements of small iron contents are described including metallographic studies and effects of thermal cycling.

CORROSION

Corrosion. R. V. Jelinek. (*Chem. Eng.*, 1958, **65**, July 28, 114–115). A preliminary article for a refresher course on the basic concepts of corrosion.

Exploring the Frontiers of Corrosion. (*Steel*, 1958, 143, July 7, 82–83). The uses of the vacuum micro-balance, the electron diffraction camera and the electron microscope in investigating the mechanism of corrosion are explained.—D. L. C. P.

Fundamental Principles of the Fight Against Corrosion in the Chemical Industry. R. Marpon. (*Peint. Pig. Ver.*, 1958, **34**, Nov., 491–498). Conditions in the industry in very aggressive atmospheres are described and the use of suitable protective coatings on carefully prepared surfaces is recommended. Paints are considered in the main, and signs of breakdown before corrosion appears, frequency of repainting, and costs are discussed.

Surface Area Relationships in Polarisation and Corrosion. M. Stern. (*Corrosion*, 1958, **14**, July, 329t–332t). The behaviour of surfaces containing regions exhibiting different overvoltages is described. The effect of cathode area fraction on corrosion is considered for the case of activation polarisation as controlling factor and it is shown that the rate is most sensitive to changes of area when the surface is largely either cathodic or anodic. The corrosion current reaches a maximum when the surface is equally divided between these.

Inter Society Corrosion Committee Glossary of Corrosion Terms. (*Corrosion*, 1958, **14**, July, 319t–320t).

Corrosion Rate of Wrought Iron. (*Prod. Eng.*, 1958, **29**, Sept., B5; from *Byers Technical Bulletin*). Reasons for comparatively high resistance of wrought iron to corrosion are its fibrous silicate inclusions and the greater adhesive power of the scale formed due to "anchoring" by the silicate fibres.

Corrosion of Steel in Moist Air. J. T. Crennell. (*J. Appl. Chem.*, 1958, **8**, Apr., 270–272). Specimens of steel stored at room temperature at ~100% relative humidity showed no corrosion after 7 years. W. H. J. Vernon. (Aug., 469–471). Conditions of exposure to vapour in the experiments of J. T. Crennell, W. S. Patterson and the author are compared to explain discrepancies reported.

Corrosion of Metals in Tropical Environments. II. Atmospheric Corrosion of Ten Structural Steels. C. R. Southwell, B. W. Forgeson and A. L. Alexander. (*NRL Report* 5002, *PB*, 131175, 1957, Dec. 11, pp. 16). Tests for 8 years at inland and marine tropical locations are reported. Mild steel with scaled or pickled surfaces, unalloyed and low-alloy Ni–Cr steels and four proprietary low-alloy steels, and also a copper-bearing steel were tested. The tests continue.

The Intercrystalline Corrosion of Stainless Steels. C. Edeleanu. (*Chem. Ind.*, 1958, Oct. 18, 1360–1361). Three types of corrosion not due to carbide precipitation and occurring in steels fully stabilized, are noted. Corrosion in caustic solutions with heavy heat flux through the steel, failure of low C 18–8 Mo steel is concentrated chloride solutions and corrosion in fused chlorides. Mechanisms are suggested.

An Investigation of the Inter-Crystalline Corrosion Tendency of Chromium–Nickel Steels used in the Passive State by Means of Potentiostats. M. Pražak. (*Werks. Korr.*, 1958, **9**, Aug.-Sept., 517–519). The results reported show that the use of the potentiostat is superior to conventional methods in that it is more sensitive to intercrystalline corrosion and enables the δ-ferrite and the σ-phases to be more readily identified.—L. J. L.

The Effect of Dust on the Atmospheric Corrosion of Metals. K. Barton. (*Werks. Korr.*, 1958, **9**, Aug.-Sept., 547–549). It was found that dusts of high adsorptivity for steam and SO_2 had no effect; that dusts with a content of constituents containing Cl^- and SO_4^{--} will have some little aggressive effect in clean atmospheres, and that in the case of iron, even dusts having a small content of constituents capable of leaching out will form centres of corrosion, which will however spread very slowly unless corrosion stimulants are present.—L. J. L.

Underground Corrosion. A Summary of 45 Years of Research. (*N.B.S. Tech. Bull.*, 1958, **42**, Sept., 181–186). A brief account of the tests carried out and the results is given, with a section on cathodic protection.

The Effect of the Physical Characteristics of Soil on the Reaction Mechanism of Corrosion of Buried Iron. T. Markovic. (*Werks. Korr.*, 1958, **9**, Oct., 623–630). Among the factors that influence the rate of corrosion of buried iron, the adhesion of water to soil is the most important. The principles of soil physics provide an explanation for the active or passive behaviour of buried iron. The possible modes of contact corrosion are illustrated by model experiments with glass spheres of various sizes.—L. J. L.

Investigations into Corrosion of Compressed Air Lines and the Preventive Action Taken. C. Tschappat. (*Werks. Korr.*, 1958, **9**, Oct., 613–623). The general principles of galvanic cells are discussed; the behaviour of the various metal components of pipelines exposed to moisture and fluctuation of temperature is described; protective measures successfully adopted to combat humid atmospheres are detailed, and the requirements protective paints should satisfy are listed.—L. J. L.

Corrosion Resistance of Wrought Iron. J. P. Chilton. (*Abstracts of Dissertations, Cambridge*, 1954–1955, 1957, 182–183). Three zones are distinguished, resisting and quickly corroding zones and a very resistant zone formed by piping and rich in Cu, Ni, and P. Suggestions for piling mild steel and improving the quality of wrought iron are made.

Corrosion and the Destination of Corrosion Products in a High Pressure Power Plant. R. C. Tucker. (*Corrosion*, 1958, **14**, May, 209–212). Conditions in steam turbines are considered, with methods of control of corrosion. Water treatment, location of structures attacked, dissolved gases and oxygen removal are reviewed. Under abnormal conditions,

such as shut-down, corrosion may be difficult to combat.

Corrosion and Protection of Galvanized Steel Transmission Tower Footings. J. D. Piper. (*Corrosion*, 1958, **14**, Mar., 119–125). Galvanized steel transmission tower footings in most soils in south-eastern Michigan did not corrode except in special circumstances including burial in cinders or other coal products or direct metallic connection with more electropositive buried metal structures. Burial below the water table also caused mild corrosion. It is shown that the condition of footings can be assessed by electropotential measurements. Magnesium anodes have given adequate protection if galvanizing is in good repair.—J. F. S.

Corrosion Problems in Water Flooding. R. W. Amstutz. (*Corrosion*, 1958, **14**, May, 255–259). The detection and control of corrosion in flood conditions are discussed.

How Corrosion Affects AISI 201, 202 Steels. R. D. Merrick and C. L. Mantell. (*Mat. Design Eng.*, 1958, **47**, Mar., 156–165). The authors review the effects of substituting Mn for Ni in stainless steels in various types of corrosive environments, and then discuss the corrosion-resistance properties of the Mn-containing austenitic stainless steels A.I.S.I. 201 and 202.—G. F.

Fretting Corrosion of Large Shafts as Influenced by Surface Treatments. O. J. Horger and H. R. Neifert. (*A.S.T.M. Spec. Tech. Publ., No.* 216, 81–95). Rotating-bending fatigue tests on 7$\frac{1}{8}$-in normalized-and-tempered 0·5% C steel shaft forgings are described. Chromium plating of disc seats showed improvement but phosphate coatings had little if any effect. Model tailshaft assemblies with a 5$\frac{1}{2}$-in. propeller hub seat were also tested and the fatigue resistance was the same as that of non-welded plain C steel MIL-S-890 class B specification.

Stress Corrosion in Metals. E. H. Phelps. (*Prod. Eng.*, 1958, **29**, Aug. 4, 56–58). Mechanism is outlined and design principles to avoid it are sketched.

Crystal Growth Theory for Stress Corrosion Cracking. (*Ind. Heat.*, 1958, **25**, Apr., 696–698). Electron-microscope studies of stress corrosion in stainless steel show that in the presence of chloride ions platelets of Cr_2O_3 form and pitting occurs.

Stress-Corrosion of Mild Steel. 3. Fatigue Strength of Mild Steel Plate after Stress-corrosion or Cathodic Protection. Y. Minami and Y. Fukuda. (*Bull. Fac. Eng. Yokohama Nat. Univ.*, 1958, **7**, Mar., 23–31). The reduction of fatigue strength due to pitting in sea water and the complete protection possible by suitable impressed currents are determined on steel plates. Stress during corrosion slightly decreased fatigue limit.

Stress Corrosion of Austenitic Stainless Steel in Geothermal Steam. T. Marshall. (*Corrosion*, 1958, **14**, Mar., 159–162). Stress-corrosion cracking which occurred readily in aerated superheated steam did not occur at all if air was absent at 150° C. The tests provide experimental confirmation that cathodic depolarization by oxygen is essential to the stress-corrosion mechanism. Corrosion rate data and stress corrosion of other alloys in the steam are given. Other factors controlling the stress corrosion of austenitic stainless steel in geothermal steam are discussed.

Chemical Factors Affecting Stress Corrosion Cracking of 18-8 Stainless Steels. H. H. Uhlig and J. Lincoln jun. (*J. Electrochem. Soc.*, 1958, **105**, (6), June, 325–332). Transcrystalline cracking of 18-8 stainless steel in boiling 42% $MgCl_2$ solution was studied using U-bend plastically deformed specimens. The effects of rate of stressing, amount of cold work, addition of acid or base, anodic and cathodic polarization and pre-exposure of unstressed specimens to 42% $MgCl_2$ solution were determined. Neither pitting nor oxygen were necessary to cause cracking.

High Temperature Oxidation of Iron-Nickel Alloys. M. J. Brabers and C. E. Birchenall. (*Corrosion*, 1958, **14**, Apr., 179–182). The oxidation of Fe–Ni alloys at 1050° C in O_2 led to sub-scale formation at grain boundaries. Continued heating in an inert atmosphere produced equilibration due to oxygen dissolution and diffusion. Porosity appeared in the sub-scale, then sintered out. Several features of the iron-rich corner of the ternary phase diagram were determined. The three-phase triangle has apices near 55 weight % Ni in the alloy phase, 52·6 atomic % O_2 in the wüstite phase and 10 weight % Ni in the spinel phase. Ni is virtually absent from the wüstite which consequently has a higher oxygen content in equilibrium with an Fe–Ni alloy than with pure iron at the same temperature. A consideration of the oxidation rates of the various phases suggests that the elimination of wüstite as a stable phase should decrease overall oxidation rates by a factor of about 20, depending on the rate of growth of the spinel phase.—J. F. S.

X-Ray Fine Structure Investigations of Layers of Scale on Sintered Iron–Aluminium Materials. F. M. Oberhauser. (*Z. Metallkunde*, 1958, **49**, June, 343–345). X-Ray investigations of oxide layers formed on sintered Fe–Al showed that at 1350° C granular layers of α-Fe_2O_3 scale were formed. At 1200° the scale consisted of a fine-grained intermediate layer of Fe_3O_4 and an outer layer of α-Fe_2O_3 and Fe_2O_4. The results are discussed.—L. D. H.

The Concentration Gradient of the Iron-Ion Vacancies in Wüstite Scales and the Mechanism of Oxidation of Iron. H. J. Engell. (**Acta Met.*, 1958, **6**, June, 439–445). [In German]. The concentration of ion vacancies in wüstite formed by heating in oxygen at 650°–1000° C was determined by an electrochemical method. The results agree with Wagner's theory of scaling. The diffusion coefficients of the mobile defects are calculated and at high temperatures are greater than those obtained from measurements of self diffusion of iron in wüstite. The difference may be due to the participation of oxygen in the transport mechanism.

The Action of Oxygen on Zinc and Iron. D. E. Davies. (*Abstracts of Dissertations, Cambridge* 1954–55. 1957, 184–185). The oxidation of iron between 175–350° is examined by fine techniques.

The Spiral Growth Patterns Observed on the Sulphide Scale of Iron. K. Nishida and S. Koda. (*Metal Physics*, 1956, **2**, July, 166–167). [In Japanese].

The Reaction between Iron and Water in the Absence of Oxygen. V. J. Linnenbom. (*J. Electrochem. Soc.*, 1958, **105**, June, 322–324). At 25° C, Fe $(OH)_2$ is formed when iron and oxygen-free water react, but at 60° and 300° Fe_3O_4 is the primary product. It is not certain whether $Fe(OH)_2$ is first formed at the higher temperatures.

Symposium on Determination of Dissolved Oxygen in Water. (*A.S.T.M. Spec. Tech. Publ.* No. 219, 1958, pp. 59).

The Oxidation of Powder Compacts of Copper-Iron Sulphides. T. A. Henderson. (*Bull. I.M.M.*, 1958, July, 497–520). Cylindrical compacts of varying compositions were made and their oxidation examined thermogravimetrically.

Effect of Temperature on the Rate of Corrosion of Metals. V. V. Gerasimov and I. L. Rosenfel'd. (*Izvest. Akad. Nauk. Otdel. Khim.*, 1957, (10), 1166–1170). The effect of temperature on the rate of corrosion of a number of metals, including iron was investigated, in various corrosive solutions containing one or more of the following: NaCl, NaOH, HCl and $KMnO_4$.

The Mechanism of Stress Corrosion of Austenitic Stainless Steels in Hot Aqueous Chloride Solutions. K. W. Leu and J. N. Helle. (*Corrosion*, 1958, **14**, May, 249–254). Alternation of corrosion and mechanical cracking is demonstrated where sharp-edged pits initiate and propagate the cracks by acting as stress-raisers and produce conditions of notch brittleness. At high stresses small pits may cause cracking, but at low stresses only long pits formed at slip bands initiate it. Initial attack is shown to depend upon the behaviour of the passivating film and only to a minor extent on metal structure. Small changes in composition and hence in type of initial attack may prevent or accelerate the effects.

Thin Metal Film Corrosion Indicators. D. Roller. (*Corrosion*, 1958, **14**, June, 263–267). Tests were carried out to find a thin metal film for packaging with hardware to act as a visual and electrical corrosion indicator. Thin iron films deposited on glass or plastic were used of various thicknesses and at humidities from 0–100%. Visual detection was easy but electrical resistance changed only when corrosion was considerable.

Development of the Redox Probe Field Technique. F. E. Constanzo and R. E. McVey. (*Corrosion*, 1958, **14**, June, 268–272). A method of soil examination for plotting pH profiles is described. The apparatus is rugged enough for field use.

A New Dynamic Test Facility for Aqueous Corrosion Studies. S. Greenberg, J. E. Draley and W. E. Ruther. (*Corrosion*, 1958, **14**, Apr., 191–192). A new aqueous corrosion test loop is described which can operate at 360° C, 3000 psia and 20–30 ft/sec. velocity past the test specimens with more precise control of corrodent composition than hitherto.

Basic Concepts and Practical Aspects of Field Corrosion Investigation. Maurice A. Riordan. (*Corrosion*, 1958, **14**, Apr., 171–174). The derivation of electrical field testing techniques for corrosion in soil or water from basic electrical concepts is explained. Pertinent characteristics of a simple corrosion cell are reviewed. A Fundamental Corrosion Circuit Reference Diagram is presented for use in relating electrical field measurements to corrosion characteristics.—J. F. S.

An Electrical Resistance Method of Corrosion Monitoring in Refinery Equipment. A. J. Freedman, E. S. Troscinski and A. Dravnieks. (*Corrosion*, 1958, **14**, Apr., 175–178). Electrical resistance corrosion probes have been used to obtain a continuous quantitative monitoring of the corrosion rates in refinery equipment during operation. The method has been used at high temperatures and in inaccessible places in vapour and liquid phases of both oil and aqueous media. Rapid evaluation of corrosion inhibitors in actual use has been obtained, only a few h being required for the effects to become noticeable.—J. F. S.

Some Considerations in the Design and Application of an Electrical Resistance Corrosion Meter. G. A. Marsh and E. Schaschl. (*Corrosion*, 1958, **14**, Mar., 155–158). The use of probes which are inserted into corrosive media and of the ancillary electrical equipment required to measure the change in resistance as they corrode are discussed. A wide range of probe sizes and types have been used in the petroleum industry. Temperature compensating elements are incorporated. Design features are discussed. Suitably placed probes do not interfere with normal plant operation. Pitting corrosion is not detected by this method.—J. F. S.

Use of a Condensate-Corrosion Tester for the Survey of Return-Line Deterioration. A. A. Berk. (*Corrosion*, 1958, **14**, Mar., 141–144). A condensate-corrosion tester is described that has been used extensively to study the corrosion occurring in condensate return pipes. A composite nipple holds six mild steel rings, each $\frac{1}{2}$ in. long which fit accurately in a wider pipe so that the inner faces of the rings form the test surface. Weight loss determinations and visual examination of many rings have built up sufficient experience to enable the economic feasability of chemical protection of condensate piping to be assessed. The tester is suitable for examining corrosion in other condensate-like water systems.—J. F. S.

Laboratory Testing of Railroad Diesel Cooling System Corrosion Inhibitors. J. I. Bregman and D. B. Boies. (*Corrosion*, 1958, **14**, June, 275–279). Two tests were used and the results correlated well with field experience.

Laboratory Studies Relating Mineral Quality of Water to Corrosion of Steel and Cast Iron. T. E. Larson and R. V. Skold. (*Corrosion*, 1958, **14**, June, 285–288). Tests at various rates of flow with air-saturated waters containing various normal constituents of domes-

tic supplies and with CO_2-controlled pH are reported.

Accelerated Condensation Corrosion Test for Evaluating Rust Preventives. E. A. Dieman and J. W. Gaynor. (*Corrosion*, 1958, **14**, June, 302–304). A test taking one-twentieth to one-fiftieth of the time and with three times the precision of the JAN-H-792 humidity cabinet test is developed in which accelerated condensation, closely controlled, with a new panel preparation procedure is used.

Experimental Research on Anticorrosion and Antifouling of Steel by Cathodic Protection. N. Koyama. (*Bull. Fac. Eng. Yokohama Nat. Univ.*, 1958, **7**, Mar., 45–64 + 11 plates). A PbO_2 anode was used and with sufficient anode current marine growths were inhibited or delayed.

Long Period Tests of the Corrosion of Painted Steel Exposed to the Atmosphere. P. Nylen. (*Peint. Pig. Ver.*, 1958, **34**, Mar., 116–117). Swedish tests at 8 locations are briefly reported. The panels were put out in 1938–1945 and life is related to climatic conditions.

A Study of the Effect of Chloride Ion on Films Formed on Iron in Sodium Nitrite Solutions. G. W. Mellors, M. Cohen and A. F. Beck. (*J. Electrochem. Soc.*, 1958, **105**, June, 332–338). The effect of chloride on the potential of Armco iron in sodium nitrite solutions and the structure of the surface films produced were studied by electron diffraction and electron microscopy. In the absence of Cl ions, the potential is noble and a film of γ-Fe_2O_3 is present. When Cl is added, the potential becomes less noble and unsteady, and inclusions of γ-Fe_2O_3, H_2O grow in the film.

Effect of Amines on Polarization of Iron Electrodes. A. F. Schram and L. R. Burns. (*J. Electrochem. Soc.*, 1958, **105**, May, 241–245). An apparatus for study of polarization in N H_2SO_4 is described. The findings can be interpreted in terms of apparent area changes brought about by amine adsorption. The inhibiting efficiency of the amines is a linear function of this apparent surface %, but as the amines show considerable specificities the action of the amine may be more than a simple masking of the surface.

Inhibition of Corrosion of Steel by Tetramethylammonium Bromide. R. Macy, B. L. Harris, W. C. Bull and J. W. Eastes. (*Corrosion*, 1958, **14**, June, 280–282). Corrosion by bis-(2-chloroethyl) sulphide (mustard gas) is inhibited by $(CH_3)_4NBr$, 1%.

Study of the Compatibility of Floating-Type Inhibitors and Cathodic Protection. E. R. Streed. (*Corrosion*, 1958, **14**, Mar., 150–154). The experimental use of floating-type inhibitors and cathodic protection simultaneously to protect steel ballast compartments against corrosion by sea-water resulted in a five-fold drop in current requirement to protect the immersed zone. The intermittently submerged and the non-submerged zones were effectively protected by the inhibitor, there being no detected interference with the protective action of either method due to the presence of the other. Theoretical aspects are discussed.—J. F. S.

Mechanism of the Corrosion of Metals in Narrow Gaps and Fissures. II. Corrosion of Iron in Solutions of Inhibitors. I. L. Rosenfel'd and I. K. Marshakov. (*Zhur. Fiz. Khim.*, 1957, **31**, (1), 72–82). An investigation is described of the corrosion stability of cracks of various width in iron immersed in a number of inhibitors. The influence of temperature and concentration of the inhibitors was determined, and the mechanism of "crevice corrosion" is explained on the basis of the results.

Service Performance of Cast Magnesium Alloy Anodes. G. L. Christie. (*Corrosion*, 1958, **14**, July, 337t–340t). Use on ships is described. Anode designs were tested, all of AZ–63 alloy, in which the effects of inverse segregation were observed. Laboratory tests showed differences between outside and inside metal which accounted for the corrosion pattern observed in ship trials.

ANALYSIS

Chipless Absolute Method of Analysis of Metals and Alloys. A. G. Loshkarev. (*Zavods. Lab.*, 1958, (8), 939–940). The method determines, in an arbitrarily chosen specimen, the quantitative content of the main component and of the admixtures, with subsequent calculation of the percentage content of the admixtures in the alloy according to some appropriate formula. It has been applied to carbon, and to some special steels, to irons, Al alloys, Ni and some other metals and alloys. It makes possible chemical analysis of very thin layers of the order of 10^{-2} to 10^{-4} mm.—L. H.

The Use of Perchloric Acid in the Metallurgical Laboratory. B. Bieber and Z. Večeřa. (*Hutn. Listy*, 1958, **13**, (7), 637–639). Analytical uses of perchloric acid are discussed, and the precautions necessary in dealing with this dangerous liquid are considered.—P. F.

Contributions to Iron-Works Chemistry: Analysis of Ferro-Alloys and Deoxidation Agents (1953 to the Beginning of 1957). J. Bruch. (*Stahl Eisen*, 1958, **78**, Aug. 21, 1209–1211). A review of analytical methods based on information published in the literature and dealing with: Ferrosilicon, ferromanganese, ferrochrome, ferrotungsten, ferromolybdenum, ferrotitanium, ferrotantalum–niobium, aluminium and calcium. (31 references).

Determination of Gases in Steel by Vacuum Fusion—Mass Spectrometry. J. F. Martin, J. E. Friedline, L. M. Melnick and G. E. Pellissier. (*Trans. Met. A.I.M.E.*, 1958, **212**, Aug., 514–519). Gases in steel, particularly small amounts of O_2 and N_2, are determined in 40 min by vacuum extraction followed by mass spectrometry.

Investigations of the Selective Separation of Iron by Solvent Extraction. H. Specker. (*Archiv. Eisenh.*, 1958, **29**, Aug., 467–470). Methods are reviewed, with reference to the literature, for the selective separation of iron from a member of elements. The systems methyl *iso*butyl ketone (4-methylpentan–2-one)—aqueous HCl and methyl *iso*butyl ketone—aqueous lithium chloride are particularly satisfactory.

The Determination of Iron in Rich Iron Ores. J. Michal and J. Žalud. (*Hutn. Listy*, 1958, **13**, (7), 639–641). A rapid method of analysing iron ores is described. The sample is first dissolved in a mixture of perchloric and phosphoric acids, the ferric ion is reduced to ferrous by means of silver, and the iron is then potentiometrically titrated with potassium dichromate.—P. F.

Determination of Metallic Iron in Presence of Ferrous and Ferric Oxides. I. T. Taranenko. (*Zavodsk Lab.*, 1958, (10), 1184–1185). Four methods for the determination of metallic iron in the presence of iron oxides are mentioned. For the analysis of the iron content in various technical asbestos fabrics, the method based on the treatment of the substance tested with iron chloride is, in the author's opinion, most suitable. Christensen's method uses iron chloride. The author describes a modification of the iron chloride method and gives some results of analysis carried out by both methods; in the author's opinion Christensen's method gives too high values for metallic iron. The time necessary for the test is about 1 h by the author's method, whilst Christensen's test requires 25 h.—S. S.

Determination of Carbon in Titanium, Zirconium and Their Alloys by Gravimetric and Conductometric Methods. D. F. Wood and M. Williams. (*Metallurgia*, 1958, **58**, July, 47–52). The gravimetric and conductimetric methods described are suitable for the determination of carbon contents from 0·02 to 0·20%. Argon is used to moderate the oxidation reaction, and a mixed flux of bismuth and iron is recommended.

The Determination of Oxygen in Steel by the Gotta Process. E. Stengel. (*Arch. Eisenh.*, 1958, **29**, June, 351–352). Gotta's Al diffusion method for the determination of oxygen in steel was investigated and compared with results obtained by the vacuum fusion method. On the whole, results were in satisfactory agreement, but with a higher scatter; low figures were obtained with higher contents, due to incomplete reduction of the oxide.

The Determination of Oxygen in Steel by Various Methods of Analysis. E. Grossfuss. (*Neue Hütte*, 1958, **3**, Oct., 608–615). Ten steels have been analysed by the hot extraction method, the Gotta method, and the residue separation process according to Klinger and Koch, and the results are compared. For eight of the steels, the results agreed; for the remaining two steels, the values obtained by the residue separation method were lower than those obtained by the other methods.—L. J. L.

Oxygen in Cast Iron. G. Östberg. (*Gjuteriet*, 1958, **48**, (6/7), 97–104). The amount of oxygen that can be dissolved in cast iron is calculated from the system Fe–O–C–Si. The application of the method to the determination of oxygen in malleable cast iron is described.—L. D. H.

The Thermoelectric Determination of Silicon in Cast Iron. G. Bierwirth. (*Giesserei*, 1958, **45**, Sept. 11, 546–549). Experimental results are reported, and literature is quoted, to demonstrate that, if only certain experimental conditions are maintained, the gravimetric determination of Si in cast iron can be replaced by a thermoelectric method. Time is saved; no chemicals are required; a degree of accuracy of ± 0·04%Si is achieved.—L. J. L.

Rapid Determination of Silicon in Cast Iron. (*Fonderie*, 1958, **148**, May, 239–240). A method is described for the absorptiometric determination of silicon in cast iron, based on measurement of the yellow Si–Molybdic complex. Absorption is measured at 400–425 mμ.

Investigations on Colorimetric Methods of Metallurgical Analysis. Part VI—Estimation of Silicon in Cast Iron Using the Duboscq Type of Colorimeter. G. V. L. N. Murty. (*Metallurgia*, 1958, **58**, July, 52–54). The method described can be completed in 15 minutes. Based on the measurement of the molybdenum-blue colour, the time required was reduced to a minimum by taking into account several factors which are discussed in detail. Data are given to show that the results compare satisfactorily with those obtained by a rigidly-controlled gravimetric method, over a range of 0·8–2·0%Si.

The Determination of Aluminium, Silicon, Vanadium and Chromium Nitrides in Carbon and Low-Alloy Steels. E. Wrzesinska. (*Prace Inst. Hutn.*, (3), 180–184). These experiments confirmed the observations of Beeghly and Urbain on the marked connection between the aluminium nitride content and the heat treatment of such steels. Their method of determining the AlN content of carbon steels may also be used for steels containing about 0·4%C + 1%Cr as well as low-alloy steels containing 0·6–1·5%Si and correspondingly 1·5–0·6 Mn. CrN, insoluble in acids, which forms in steel containing Cr, may also be determined by the chemical method, by determining the total content of N and that of N soluble in acids, since Cr is the only component in this steel capable of forming a nitride which is insoluble. Si_3N_4 occurring in low alloy steels with a varying content of Si and Mn may likewise be determined by assessing the total N content and the content of N dissolved. It is not essential to use the vacuum melting method, as suggested by Sloman, since the precipitate may be dissolved in concentrated H_2SO_4 with a considerable addition of K_2SO_4.—M. T.

Use of Complexones in Analytical Chemistry. LII. Detection of Boron, Germanium, Niobium and Tantalum by Means of Pyrocatechol Violet. V. Patrovský. (*Coll. Czechoslovak Chem. Comm.*, 1958, **23**, Mar., 549–550). The conditions are examined under which the coloured complexes formed by B, Ge, Nb and Ta with pyrocatechol violet can be used for their detection.—L. D. H.

Rapid Method for Determination of Calcium Oxide in Flux-coated Sinters, Calcites, Dolomites and Slags. V. D. Konkin. (*Zavods. Lab.*, 1958, (10), 1181–1183). A detailed description of a chemical method for the rapid determination of CaO in blast and O.H. furnace slags and other similar substances

is given. Triethanolamine was used and the alkalinity was controlled with indigo carmine. The test takes up to 15 min, on the average 8–10 min were needed. The error did not exceed ± 0·20% for CaO contents up to 15%, for contents of 15–36%, the error was less than ± 0·35%. Three other chemical methods using various reagents give equally exact results, but the tests require a longer time.

Contribution to the Chemistry of Iron and Steel: Spectrochemical Analysis (1953 to 1957). G. Hartleif. (*Stahl Eisen*, 1958, **78**, June 12, 837–839). A review of published information dealing with: Steels, Pig iron, Ferro-alloys, Ore and Slag, Refractories, and Preparation of the samples.—T. G.

Methods of Evaluation and Sources of Error in Quantitative Photoelectric Spectrographic Analysis. H. Diebel. (*Arch. Eisenh.*, 1958, **29**, May, 275–281). Methods of evaluation of photoelectric methods of spectrographic analysis are described; systematic errors and those due to scatter are discussed, and the possibilities of sufficiently accurate determination of major constituents are pointed out. A discussion follows the paper.—L. D. H.

Iron-Base Spectroscopic Standard Samples. (*N.B.S. Tech. Bull.*, 1958, **42**, Oct., 205). Compositions of 8 new samples are given with an account of their preparation.

Results of the Application of Direct Spectrographic Analysis to the Iron and Steel Industry. V. Mathien. (*Groupement pour l' Avancement des Méthodes d'Analyse Spectrographique des Produits Métallurgiques*, 19th Congress, Sept., 1956, 149–154). A short account is given of the results obtained in the use of direct spectrographic analysis for process control in iron and steel works in the Liège basin.

Quantitative Spectrochemical Analysis of Carbon in Steels. A. Pokorny. (*Hutn. Listy*, 1958, **13**, (10), 892–899). A description is given of a rapid non-destructive method of determination C in steels up to 0·05%C. A comparison is given between the results obtained with the apparatus described and by chemical analysis. The apparatus consists of a quartz spectrograph and a spark generator—M. T.

On the Rapid Spectrochemical Analysis of Si in Molten Steel. Y. Terauchi. (*Sumi. Met.*, 1957, **9**, Oct., 221–230). Optimum conditions are established for making a spectrochemical analysis for silicon in 10 min. from sampling. Modifications to the direct-reading Quantoreader for rapid analysis of silicon are also described. (13 references).

The New Standard Quantometer 14000. W.-H. Barry and P. Hourlier. (*Groupement pour l' Avancement des Méthodes d' Analyse Spectrographique des Produits Métallurgiques*, 19th Congress, Sept., 1956.) The characteristics and performance of a new A.R.L. standard quantometer are described.—L. D. H.

Some Experiences in the Use of the "Quantovac" in a Steelworks Laboratory. S. Muir. (*J. West Scotland I.S.I. preprint, No.* 516, 1958, Dec. 12, pp. 12). A device for analysis by sparking in an oxygen-free atmosphere. The determination of C, S, P, Mn and Si takes 5 min.

A Rapid Works Method for the Estimation of the Amount of Impurity Elements in Ferrosilicon. O. Bělohlávek. (*Hutn. Listy*, 1958, **13**, (5), 426–428). Details are given of a rapid and economical spectrographic method of determining elements such as Al, Mn, Cu, Ti and Ni in ferrosilicon.—F. F.

The Spectrographic Analysis of Silico-Alumina Refractories. A. M. Morand. (*Groupement pour l' Avancement des Méthodes d' Analyse Spectrographique des Produits Métallurgiques*, 19th Congress, Sept., 1956). A high-dispersion Hilger spectrograph was used, with D.C. arc excitation. The finely-divided sample was ignited at 1 200° C, as it was found that volatile matter interfered and caused ejection losses, and mixed with carbon, nickel and B_2O_3. Ni was used as an internal standard, and it was found that the addition of B_2O_3 improved reproducibility.

Radioisotopes in Industry and Metallurgy. (*Mét. Constr. Mécan.*, 1958, **90**, June, 449–461). A general survey is given of the development of the industrial use of radioisotopes. The apparatus used is described, including protective measures, and a section is devoted to the use of radioactive isotopes in metallurgical research.

The Use of Radio-Isotopes in Metallurgy. S. Simon. (*Kohászati Lapok*, 1958, **13**, Feb.-March, Öntöde, 42–46). The use of radio-isotopes in metallurgy and foundry practice is reviewed, and the measurement of the radiation is described—P. K.

Design and Equipment of a Modern Laboratory for an Iron and Steel Works. P. Dickens. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1597–1603). Design and construction of the new chemical laboratory of the Mannesmann Hüttenwerke A.G., its energy supply, ventilation and analytical equipment are described. From the layout and the main equipment the wide scope of the laboratory in routine analytical control of production and in research work can be seen.—T. G.

INDUSTRIAL USES AND APLICATIONS

Railroad Car Rebuilds and Repair at Kaiser's Fontana Works. A. B. Stoker. (*Iron Steel Eng.*, 1958, **35**, Aug., 132–137). Economies achieved in the rebuilding, re-design and maintenance of works railroad wagons of various types are discussed.

The Selection of Constructional Materials for Individual and Mass Production. A. Erker. (*V.D.I.Z.*, 1958, **100**, Sept. 1, 1197–1209). The strength and the processing characteristics of constructional materials are discussed under the following heads: determination of permissible loads; choice of material; overload calculations; load fluctuations; casting and welding; methods of combining cast and rolled materials; heat treatment; machinability; the effects of mass production; the use of light metals. (63 references).—L. J. L.

A.S.T.M. and S.A.E. Grade Markings for Steel Bolts. (*Prod. Eng.*, 1958, **29**, Sept., G, 17; from *Fasteners*). A table is given.

Wrought Steels for the Petroleum Industry. S. Barraclough. (*Ind. Petroleum Rev.*, 1958, **12**, Nov., 370–374). A review of carbon and low and high alloy steels, their properties and uses.

Steels for the Petroleum Industry. A Comparison of British and American Qualities. Part I. F. A. Kirk and J. Williams. (*Corros. Techn.*, 1958, **5**, Oct., 316–318). The causes of corrosion in the petroleum industry are considered and a comparison is made between the various standard steels developed in Britain and America to withstand this corrosion.—A. G.

The Use of Carbon Steel for the Production of API-E Boring Tubes. R. Sejnoha and V. Smid. (*Hutn. Listy*, 1958, **13**, (10), 878–881). Under normal hardening conditions the differences between the mechanical properties of the stamped end and the body of boring tubes are too great to be acceptable. These differences result from the difference in cross-section. Experiments were carried out on the hardening of tubes when moving them through a continuous furnace at rates of 0·7 to 1·2 m./min. By choosing a suitable rate of motion through the furnace and appropriate use of the quenching spray, it was found possible to obtain approximately equal mechanical properties for the two parts of the tubes in steel containing 0·44%C, 0·80%Mn, 0·38%Si, 0·032%P and 0·021%S.—M. T.

Steels for Synthesis Gas and Hydrogen. V. Cihal. (*Werks. Korr.*, 1958, **9**, Aug.-Sept., 513–514). Cr–Mo steels suitable for hydrogen were found to be less than ideal for the synthesis mixture. The development of W–Ti steels is described. The steel recommended for synthesis gas has a maximum content of 0·12%C, 0·4–0·8%Ti, and 3·6%W.—L. J. L.

Steels for Use in the Chemical Petroleum and Allied Industries. (*B.S.* 1501–1506: 1958 and 1510: 1958). The subjects covered are: Carbon and Alloy Steel Plates, Sections and Bars; Carbon and Alloy Steel Castings; and Carbon and Alloy Steel Bars for Bolting Material. The steels are carbon, C–Mn, C–Mo, 3½%Ni, Cr–Mo, 13%Cr, austenitic Cr–Ni, Cr–Ni–2½%Mo and Cr–Ni–3½%Mo. 1510 gives conditions for low-temperature service, excluding castings.

Cast Stainless Pump Handles Corrosive Electrolytes. E. A. Schoefer. (*Plating*, 1958, **45**, Apr., 366–367). The use of cast stainless steel pumps in the heavy copper plating of steel wire is described.

Ductile Iron in Use for Chemical Pumps. R. R. Rhodes. (*Chem. Eng. Prog.*, 1958, **56**, Sept., 116). Types 60–45–10 and 80–60–03 are used, the latter for extreme wear resistance. Thermal shock tests were applied. The properties of the two materials are tabulated.

W-545 . . . a Better Turbine Disc Alloy. J. T. Brown. (*Metal Progress*, 1958, **74**, Aug., 87–90). A new iron-base turbine disc alloy having a good combination of high temperature stress-rupture strength and ductility, and low-temperature tensile strength has been developed and used; its properties are described and explained. 0·005 to 0·15%B increases the inherent ductility of the present austenitic precipitation-hardening alloys. Further strengthening, by additions of larger amounts of Ti is then possible without allowing the material to become notch-sensitive.—D. L. C. F.

Status of High-Strength Steels for the Aircraft Industry. R. J. Nekervis, C. H. Lund and A. M. Hall. (*Titanium Metallurgical Lab. Report* 91, 1958, Jan. 3, pp. 95; *PB* 121639). A survey of 12 steel producers and 18 aircraft manufacturers disclosed 6 classes of steel which showed promise for aircraft construction and is decreasing order of tensile strength at 800° F there were: Hot-work tool steels, martensitic stainless, low-alloy hardenable, precipitation-hardening semi-austenitic stainless, cold-rolled austenitic stainless and precipitation-hardening austenitic stainless steels. Up to 1000° F the first three afford the highest available ductility and the air-hardening steels which distort less than steels needing quenching are the more suitable for aircraft uses. Tempering conditions and their effects are discussed.

Preview of Space Metals: Steels. (*Met. Prog.*, 1958, **74**, Oct., 101–102). A brief account of tool steels, stainless types and their properties and uses in the B-70 aircraft.

Steels for the Construction of Nuclear Power Stations. H. Krainer. (*Berg-Hutten. Monatsh.*, 1958, **103**, July, 125–136). After outlining the mechanism of neutron absorption, absorption by elements commonly alloyed with steel is dealt with. The deleterious influence of high-energy irradiation is discussed, with reference to boiler steels and chemically resistant steels, and it is shown that these harmful effects are reduced at the elevated temperatures found in nuclear reactors Corrosion problems, and the effects of radiation in corrosion are mentioned, the importance of weldability is emphasized, and the applications of B steels and compounds of steel and rare-earth oxides are discussed.

Transcripts of Symposia on Economic Comparison of Zirconium and Stainless Steel in Nuclear Power Reactors. (*Columbia-National Corporation Symposia in New York*, Feb., 1958 *and Pittsburgh*, Mar., 1958, pp. 105). **Summary Report.** M. Benedict. (pp. 31).

Application of Cold-Rolled Electrotechnic Steel Sheets in the Construction of Transformers and Electric Motors. A. Sliwowa. (*Hutnik*, 1957, **24**, July-Aug., 304–311). [In Polish]. The advantages of cold-rolled steel sheets are discussed. The author suggests that in order to become familiar with the problems of applying cold-rolled steel in the construction of transformers it would be advantageous to import such steel from abroad.

HISTORICAL

An Iron Smelting Works of the 16th Centruy in Paintings. (*Demag Nachrichten*, 1958, (151), 14–15). A section of a painting by van Valckenborch is shown, which depicts the smelting of iron in the 16th century.

Cast Irons of the Old Belgian Founders. R. Evrard. (*Fond. Belge.*, 1958, **28**, Sept.-Oct., 284–288). A review of development in the properties and applications of cast iron

produced in the Belgian foundries from the 16th to the mid-19th centuries.

A 1 600-Years Old Corrosion-Resistant Wrought Iron Column in India. L. Takáts. (*Koh. Lapok Öntöde*, 1958, **9**, May-June, 133). The author describes, with a photograph, the corrosion-resistant wrought iron Quatob Column in New Delhi. The column was probably made by forge-welding, the composition of the metal being: C 0·08%, Mn 0·0%, Si 0·046%, S 0·06%, P. 0·114%, Cu 0·034%.

Wilhelm Siemens and the Electric Arc Furnace Invented by Him. The 75th Anniversary of his Death. L. Arends. (*Electrowarme*, 1958, **16**, Oct., 350–353). His electrode control system is described and public demonstrations of arc melting are recalled. His influence on Héroult is noted.

The History of Edgar Allen & Co. Limited. (*Edgar Allen News*, 1958, **37**, Nov., 241–244).

ECONOMICS AND STATISTICS

Steel. (*Bol. Min. Indust.*, 1958, **37**, June, 307–309). The steel production of "Central Sidcrurgica" for 1957 is analysed.

Iron and Steel. J. C. O. Harris. (*U.S. Bur. Mines, Min. Yearbook*, 1956, **1**, 613–639). **Iron and Steel Scrap.** J. E. Larkin. (641–669). Statistical.

Outline of the Iron and Steel Market. T. Hagtingius. (*Metalen*, 1958, **13**, Aug. 30, 294–295). An outline of the production and value of European and U.S. iron and steel during 1958.

Industrial Production and Steel Consumption. (Sir) R. Shone and H. R. Fisher. (*J. Roy. Stat. Soc.*, 1958, **121**, (3), 269–311). The relation between these is worked out, with predictions for 1962.

A Giant Today, Bigger Tomorrow—The Steel Industry. (*Steel*, 1958, **143**, Sept. 15, 149–151). By 1975 American steel capacity is estimated to reach nearly 200 × 10^6 tons. Present capacity and that scheduled for 1959 should be adequate until 1961.—A. G.

Chromium. W. McInnis and H. V. Heidrich. (*U.S. Bur. Mines, Min. Yearbook*, 1956, **1**, 339–354). **Cobalt.** H. W. Davis and C. R. Buck. (379–387). **Niobium and Tantalum.** W. R. Barton. (393–407). **Manganese.** G. L. DeHuff and T. Fratta. (789–812). **Molybdenum.** W. McInnis and M. J. Burke. (857–868). **Nickel.** H. W. Davis. (869–887). **Tungsten.** R. H. Holliday and M. J. Burke. (1225–1244). **Vanadium.** P. M. Busch and K. W. McNulty. (1291–1300). **Zirconium and Hafnium.** G. C. Ware. (1363–1371). Statistical.

MISCELLANEOUS

Graphical Correlation Analysis and Its Use in the Analysis of Metallurgical Production. R. Vojta. (*Hutn. Listy*, 1958, **13**, (9), 795–800). The author prefers this method to multiple correlation analysis based on arithmetical calculation, over which its main advantages are simplicity and rapidity, provided certain limiting assumptions and a reasonable degree of accuracy are acceptable. He applies his theory to a practical analysis of O.H. furnace production of tube steel.—M. T.

Statistical Control Cards for Materials Flow and Quality Control. J. Sittard. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1585–1597). The author describes a card system for materials flow and quality control that has the advantage over all other systems as remedies may be applied as soon as any deviation from the nominal value occurs and that allows an evaluation of the information from any required point of view.—T. G.

Systematic Accident Prevention. A Contribution to Protection Against Accidents in Foundries. (*Giesserei*, 1958, **45**, Sept. 25, 610–615). A procedure is developed for prevention of accidents by systematic examination of their causes and the adoption of certain measures to prevent their future occurrence.

Health and Safety in Foundries. (Sir) G. Barnett. (*Trans. A.F.S.*, 1957, **65**, 17–30). A review, mainly of dust control with sections on fume, other hazards, and first-aid requirements. (51 refs.).

New Training Programme for the Executive Staff of the French Metallurgical Industry in Respect of Works Safety and Health. J. M. Cavé. (*Bol. Min. Indust.*, 1958, **37**, June, 315–317). An account of recent French developments in works-health and safety training for executive staff.

Iron Oxide Pigments. T. de Polo and E. B. Waters. (*U.S. Bur. Mines, Min. Yearbook*, 1956, **1**, 671–678). Contains a section on technology.

$FeSe_2$, A Semiconductor Containing Iron. G. Fischer. (*Can. J. Phys.*, 1958, **36**, Oct., 1435–1438).

Cultivation, Morphology, and Classification of the Iron Bacteria. R. S. Wolfe. (*J. Am. Water Works Assoc.*, 1958, **50**, Sept., 1241–1249).

BOOK NOTICES

AITCHISON, L., and W. I. PUMPHREY. "*Using Steel Wisely.*" 8½ × 5½ in., pp. xxii + 241. Illustrated. London, 1958: Macdonald & Evans, Ltd. (Price £2 4*s.*).

GREGORY, E., and E. N. SIMONS. "*The Heat Treatment of Steel.*" 2nd edition. 8½ × 5½ in., pp. xiv + 381. Illustrated. London, 1958: Sir Isaac Pitman & Sons Ltd. (Price £1 15*s.*).

"*Using Steel Wisely*" is intended more for the buyer and engineer than for the metallurgist. Even so, most metallurgists will delight at the philosophical style of the authors, applied to a subject so often rendered dull by its very nature.

The fact that no "perfectly flawless piece of industrial metal can exist" is taken as the starting point of a discussion which embraces the principles of steel selection. Even though no detailed examples of specific selection are given, this excellent book succeeds in explaining the quantitative and qualitative attributes of steel, and explains in terms easily followed by non-specialists the meanings of toughness and ductility. Part One, "Creating A Component," deals briefly with ingot making, deformation to form wrought products, heat treatment, surface treatments and quality. Part Two, "Making the Best of It," discusses the implications of Part One so far as the actual choice of steel is concerned.

"*The Heat Treatment of Steel*" is the second edition of the well-known book of the same name published in 1948. It is essentially of a practical nature, and is designed for those actively engaged in the heat treatment of steel. The present edition has a rearrangement of chapters, and has entirely new sections on the sub-zero treatment of high-speed steel, treatment of steels for moulds and hobs in the plastics industry, austempering, martempering and marquenching; these sections being extremely brief. The section on the heat treatment of magnet steels has been entirely re-written.

The book should prove of great help to personnel in the tool rooms and heat treatment shops of the steel using industries because the accent is undoubtedly on practical aspects of heat treatment rather than on the theoretical implications of this often misunderstood subject. In addition to actual heat treatment itself, related topics such as furnace, pyrometers, quenching media, nitriding, heating by induction and flame surface hardening are briefly discussed.

W. G. SALISBURY.

"*Basic Electricity.*" In Five Parts. 9¾ × 6½ in., pp. 127; 117; 122; 104; 117. Illustrated. New York; London, 1958: The Briolet Press; The Technical Press Ltd. (Price 12*s.* 6*d.* per part or 55*s.* per set).

This set of manuals in five parts, profusely illustrated by cartoon-type drawings, comprises a beginner's course in elementary electricity intended for the training of technicians and apprentices without any basic knowledge of the subject. Originally produced for the U.S. Navy training programme when a grave shortage of skilled technicians was revealed in the Korean War, they have been edited by a special R.E.M.E. team and adopted for British Army training. Similar courses are promised for elementary electronics, servomechanisms and radar.—M. L. PEARL.

DEUTSCHE GESELLSHAFT FÜR CHEMISCHES APPARATEWESEN E.V.. "*Dechema-Werkstoffe Tabelle. Chemische Beständigkeit der Werkstoffe.*" 3. Bearb. 8. Lieferung. Form to Kali. Lfd. Bl. Nr. 705–803. 12 × 8½ in., loose-leaf, 99 sheets. Weinheim Bergstrasse, 1958: Verlag Chemie G.m.b.H. (Price, Members DM. 32.00, Non-Members D.M. 40.00).

The eighth part of the Dechema Werkstoff-Tabelle follows the pattern of the earlier parts, and deals with the effects of some 45 chemical compounds on 98 metals, alloys and non-metallics; a code is used to denote the degree of attack, and there are copious notes and, frequently, descriptions of the manufacture of the chemicals themselves. The range covered is from formaldehyde to potassium nitrite ("Kaliumnitrit"); more than half the alphabet still remains to be covered. The high standard of this publication is being maintained.

J. P. SAVILLE.

"*Giesserei Lexicon.*" Edited by A. Schulenburg. 9½ × 6½ in., pp. xiv + 858. Illustrated. Berlin, 1958: Fachverlag Schiele u. Schön GmbH. (Price DM. 58.00).

This volume is far more of an encyclopedia than a lexicon, since the emphasis of the numerous entries is far more on explanation than on definition. It is extremely wide in scope, dealing not only with foundry materials and processes, but, in a general way, with the properties of metals whether they are commonly used in castings or not. This broad outlook entitles the author to include semi-biographical pieces, such as a lyrical outburst on Friedrich Wöhler, who first isolated aluminium by reducing the chloride with potassium. "*Es Krachte und polterte in dem Tiegel,*" is a mild example of the style; the article on Paul Héroult is more restrained, as are those on Bessemer and Sidney Gilchrist Thomas. Curiously, although the Siemens-Martin process is well described, there are no articles on the Siemens brothers; but the process is in fact, ascribed to Friedrich Siemens and the "brothers" Emile and Pierre Martin, who were really father and son. Martens, with no initials or personal dates, is given as the founder of metallography, and there is no reference to H. C. Sorby, who is embalmed in "*sorbitguss*"; however, the name "*austenit*" is correctly linked to W. C. Roberts-Austen. There is a lengthy and good article on the history of casting, but the chronology which succeeds it enshrines traditional errors about Dud Dudley and Abraham Darby I.

Fortunately, the technical matter seems as unassailable as it is copious and well-illustrated. A comparable volume in English would be of immense value to British foundry technicians and it is clear that, because of its breadth and detail, German foundrymen must find it a great treasure. Of equal value to him will be the lists of suppliers of cast products and of foundry requirements, to be found at the end.

J. P. SAVILLE.

"*Kempe's Engineers' Year-Book for* 1959." 64th ed., 2 vols. 6¾ × 4¾ in., vol. 1, pp. xiii + 1324. Vol. 2, ix + 1416. Illustrated. London, 1959: Morgan Brothers (Publishers) Ltd. (Price—two vols. in case—82*s.* 6*d.*).

"Kempe's" is now in its sixty-fourth edition and shows, as usual, the results of great efforts to keep it up-to-date and comprehensive. A lot of new matter has been added since the last edition; in the "Iron and Steel" section, details of electric furnaces, and in "Non Ferrous Metals and

Alloys," details of high temperature nickel alloys, for instance. The production is, as always, a credit to the publishers, the editor and the numerous contributors.—J. P. SAVILLE.

KUBASCHEWSKI, O., and E. LL. EVANS. "*Metallurgical Thermochemistry*," 3rd edition. (International Series on Monographs on Metal Physics and Physical Metallurgy, Vol. 1). 8½ × 5½ in., pp. xiv + 426. Illustrated. London, 1958: Pergamon Press, Ltd. (Price £3 3*s*.).

Apart from a few alterations to the text and tables and substantial additions to the last chapter, this new edition is identical with the second which was published and favourably reviewed (*J.I.S.I.*, 1956, **11**, **183**, 340), in 1956. In the final chapter, which gives examples of the thermochemical treatment of metallurgical problems, the page on the reducibility of magnesia has been omitted and short sections have been added on the refining of iron, the solubility of alumina in nickel, and the assessment of the very discordant thermodynamic data which now exist on silicon monoxide. The book is still the best of its kind available, but owners of the second edition would gain little from buying the third with sixteen extra pages for eight extra shillings. F. D. RICHARDSON.

LIPSON, H., and C. A. TAYLOR. "*Fourier Transforms and X-Ray Diffraction*." 8½ × 5½ in., pp. vii + 76. Illustrated. London, 1958: G. Bell and Sons Ltd. (Price 18*s*. 6*d*.).

This is an excellently produced monograph which provides an introduction to Fourier-transform theory applied to X-ray diffraction and emphasizes the physics of the subject. The authors, Professor H. Lipson and Dr C. A. Taylor, both of the Faculty of Technology, Manchester University, in relating the mathematics closely to physical principles, have sacrificed something of the strict mathematical rigidity associated with the Fourier-transform concept. Physics students and research workers should find much in this work to help them in understanding the diffraction of X-rays by crystals. M. L. PEARL.

NEEDHAM, JOSEPH. "*The Development of Iron and Steel Technology in China*." (Second Biennial Dickinson Memorial Lecture to the Newcomen Society 1956). 9¾ in. × 7 in., pp. xii + 76, 31 plates. London, 1958: The Newcomen Society for the Study of the History of Engineering and Technology. (Price 35*s*.).

China's principal contributions to the development of modern Western society have long been recognized to be gunpowder, moveable type, and cast iron. The first concise account of the last-named forms the subject of the Newcomen Society's Second Dickinson Memorial Lecture, by Dr Joseph Needham, F.R.S., one of those rare scholars who has established reputations in two widely differing spheres, biochemistry and Sinology.

Much of Dr Needham's lecture is necessarily based on the interpretation of written texts; scientific archaeology has only in recent years been enlisted to amplify the picture of China's past, and there has so far been little excavation of industrial sites. However, it is an excellent outline picture of the earlier history of ironmaking in China.

Metallic iron was produced first in the 6th century B.C., a millenium after its first appearance in the Near East, the birthplace of iron technology. The first metal produced was probably carbon-free bloomery iron, but within two centuries molten iron was produced and cast with success. There is a wealth of cast-iron objects from the 4th century B.C. onwards, and Dr Needham provides some excellent illustrations.

The early Chinese ironmasters soon learned how to make steel, by decarburizing their pig iron. This method, known as "the hundred refinings," depended on the use of an oxidizing blast of cold air, and was first practised in the 2nd century B.C.; by the 17th century A.D., it was producing something like cast steel. Parallel with this process was one of co-fusion, in which lumps of wrought iron were carburized by heating in a bath of molten pig iron. Dr Needham postulates that these two techniques may be direct ancestors of the Bessemer and Siemens-Martin processes respectively, a fascinating conjecture worthy of more detailed examination.

The Newcomen Society is to be congratulated on making this important contribution to early iron and steel technology available to a wider public. It is to be hoped that Dr Needham's challenging exploration of the interrelation of eastern and western technology will inspire other workers to turn their attentions to filling in the many gaps in existing knowledge.—H. F. CLEERE.

ROPER, FRANCIS D. "*Cores and Coremaking*." 6 × 5½ in., pp. 125. Illustrated. London, 1958: George Allen and Unwin Ltd. (Price 21*s*.).

This small book (12 pages of photographs are numbered as text and there are numerous drawings) is general in its scope; it refers equally to ferrous and non-ferrous practice and distinguishes between them where necessary. It is pleasantly written and very well produced, and the author has taken great advantage of the assistance given him by various foundries and foundry equipment making firms. As an introduction to this little-described part of the foundry art his book will be hard to surpass.—J. P. SAVILLE.

WIRTSCHAFTSVEREINIGUNG GIESSEREI-INDUSTRIE, G.D.M., "*Adressbuch der Giesserei-Industrie in der Bundesrepublik Deutschland*, 1958." 2. Auflage. 8½ × 5¾ in., pp. 442. Dusseldorf, 1958: Giesserei-Verlag G.m.b.H. (Price DM. 20.00). This is the second, enlarged edition of a remarkably full directory of the West German foundry industry. It gives the addresses of foundrymen's associations in the Bundesrepublik (and of a number of national organizations outside Germany), while the main part, arranged regionally and alphabetically, provides a guide to 2,237 firms complete with names of leading personnel, details of product, production figures, year of foundation and even, the existence or otherwise of a firm's own pattern, moulding, or machine shop. An advertisement section gives information about supplier industries.

NEW PUBLICATIONS

BRITISH STANDARDS INSTITUTION. B.S. 1016: Part 6: 1958. "*Methods for the Analysis and Testing of Coal and Coke*." Part 6. "*Ultimate Analysis of Coal*." 8½ × 5¾ in., pp. 46. Illustrated. 1958, London: The Institution. (Price 10*s*.).

BUNSHAH, R. F., (ed.). "*Vacuum Metallurgy*." 9 × 6 in., pp. xviii + 472. Illustrated. New York, London, 1958: Reinhold Publishing Corp.; Chapman & Hall Ltd. (Price £5).

"*Comptes rendus. Journees Internationales de Siderurgie*." Liége, Luxembourg, Charleroi et Bruxelles, 18–28 Juin, 1958. 11½ × 8 in., pp. 428. Illustrated. Liége, 1958: C.N.R.M. (Price 530 fr.).

"*Das Buch vom Rost. Fe_2O_3, x H_2O. Entstehen, Verhüten, Berkämpfen*." 7¾ × 4¾ in., pp. 304 + 112 + 28. Illustrated. Wiesbaden, 1958: Industrie-Verlags-GmbH. Dr. Edgar Jorg. (Price DM. 18.50).

DEUTSCHE GESELLSHAFT FÜR CHEMISCHES APPARATEWESEN E.V., "*Dechema-Werkstoff Tabelle. Chemische Beständigkeit der Werkstoffe*." 3. Bearb. 8. Lieferung. Form to Kali. Lfd., Bl. Nr. 705–803). 12 × 8¼ in., loose-leaf, 99 sheets. Weinheim/Bergstrasse, 1958: Verlag Chemie G.m.b.H. (Price Members DM. 32.00; Non-Members D.M 40.00).

DURELLI, A. J., *et al.* "*Introduction to the Theoretical and Experimental Analysis of Stress and Strain*." 9 × 6 in., pp. xxx + 498. Illustrated. New York, Toronto, London, 1958: McGraw Hill Publishing Co. Ltd. (Price £4 17*s*.).

ELLOITT, JOHN F., (ed.). "*The Physical Chemistry of Steelmaking*." Proceedings of the Conference sponsored by the Department of Metallurgy. Massachusetts Institute of Technology, 28 May–3 June, 1956. 11 × 8½ in., pp. xiii + 257. Illustrated. New York, London, 1958: The Technology Press M.I.T. & John Wiley and Sons, Inc.; Chapman & Hall Ltd. (Price £6).

MARSHALL, J. D. "*Furness and the Industrial Revolution*." 8½ × 5½ in., pp. xxiii + 438. Illustrated. Barrow-in-Furness, 1958: Central Library and Museum. (Price 23*s*.).

MUELLER, W., (ed.). "*Proceedings, Sixth Annual Conference on Industrial Applications of X-ray Analysis. Denver, August* 7–9, 1957." 11 × 8½ in., pp. [viii] + 494. Illustrated. Denver, 1958: University of Denver.

"*New Continental Oxygen-Steelmaking Processes*." Reprinted from "Iron and Coal Trades Review," August-November, 1958. 9¾ × 7¾ in., pp. 54. Illustrated. London, 1959: "Iron and Coal Trades Review." (Price 10*s*. 6*d*.).

RIEBENSAHM, P. und P. W. SCHMIDT. "*Werkstoffprüfung. Metalle*." (5 neubearb. Aufl. Werkstattbücher für Betriebsfachleute, Konstrukteure und Studierende Heft 34). 8vo, pp. 62. Illustrated. 1958, Berlin U.S.W.: Springer-Verlag. (Price DM. 3.60).

SPIZIG, SIEGFRIED J. "*Der Gesteuerte elektroerosive Metallabtrag*." (Schriftenreihe Feinarbeitung H.25). 8vo, pp. 87. Illustrated. 1957, Stuttgart: Deva-Fachverlag. (Price DM 5.80).

STIFTERVERBAND FÜR DIE DEUTSCHE WISSENSCHAFT. "*Vademecum Deutscher Forschungsstätten*." 2. Ergänztzte Auflage 1957. 9½ × 6½ in., pp. 553. Essen-Bredeney, 1957: Der Stifterverband.

"*Technical Information and the Smaller Firm*." Facts and Figures on Practices in European and American Industry. 10⅛ × 8¼ in., pp. 69. Illustrated. Paris, 1958: European Productivity Agency of Organisation for European Economic Co-operation. (Price 4*s*. 6*d*.).

VEREIN DEUTSCHER EISENHÜTTENLEUTE. "*Stahleinsatzlisten*." 170–58. 1. Ausg. Sept. 1958. "*Stähle für Werkzeuge der Schrauben-, Bolzen-, Nieten- und Mutternfertigung*." 185–58, 1. Ausg. Sept. 1958. "*Stähle für Werkzeuge der Gesenkschmiede*". 198–58 1 Ausg. Sept. 1958. "*Stähle für Druckgiessformen und Lockbeanspruchte Teile von Druckgiessmaschinen*." 4to, pp. 8, 3 and 4 resp. 1958, Düsseldorf: Verlag Stahleisen. (Prices DM 4, 1.75, and 2 resp.).

VEREIN DEUTSCHER EISENHÜTTENLEUTE. "*Vereinheitlichung der Steinformate für Stahlwerks-Verschleissmaterial und Giessmaterial*." (Bericht des Stahlwerksausschusses des Vereins Deutscher Eisenhüttenleute. 4to, pp. 8. Illustrated. 1958, Düsseldorf: Verlag Stahleisen. (Price DM. 1.50).

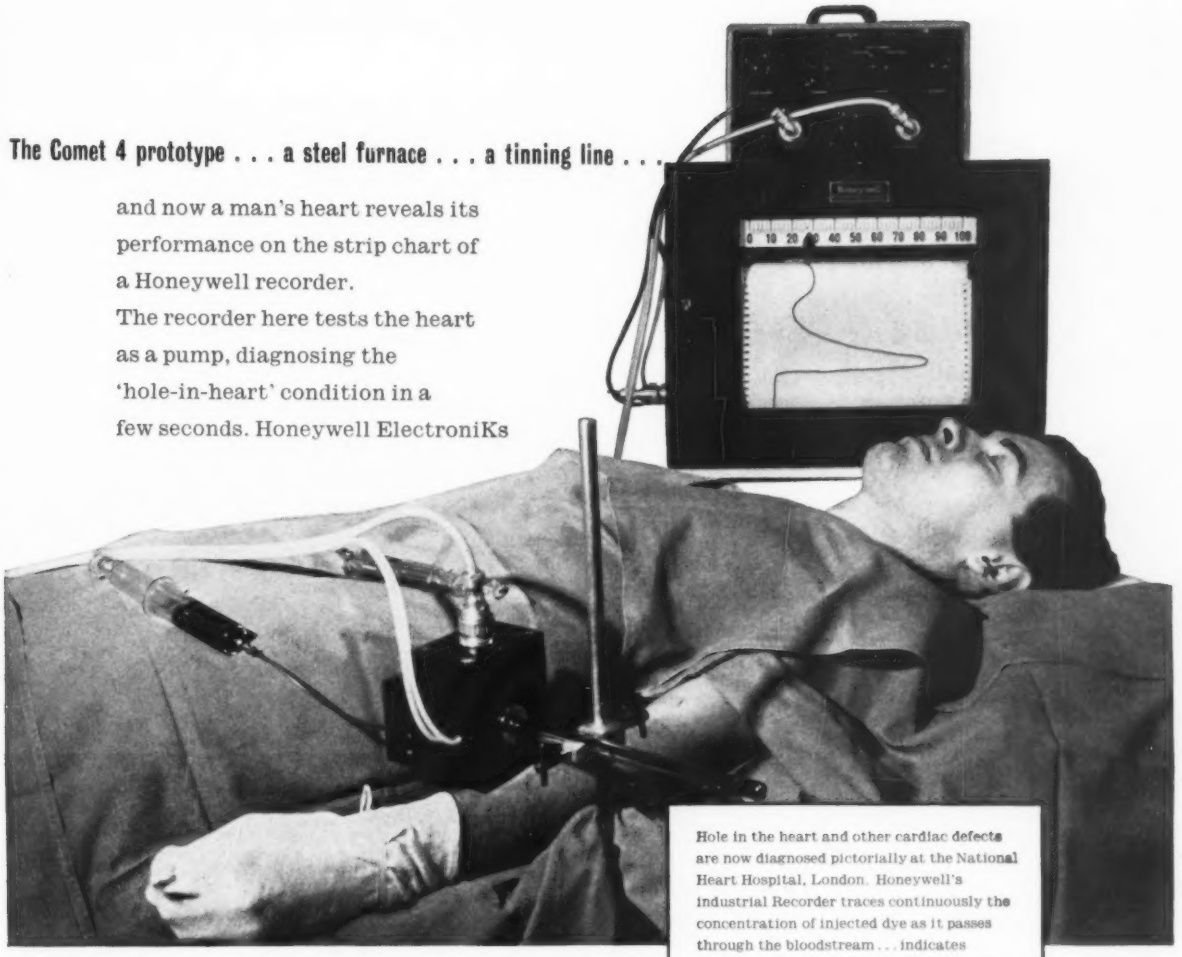
VIELHABER, LOUIS. "*Emailtechnik*." (3 Neubearb. Aufl.). 8vo, pp. 168. Illustrated, 1958, Düsseldorf: VDI-Verlag. (Price DM. 19.80).

"*Vysoké technické školy v Ceskoslovenské Republice*." 9½ × 6½ in., pp. 224. Illustrated. Prague, 1957: Statni pedagogické nakladatelstvi.

"*Wire Industry Encyclopaedic Handbook* 1959." 8½ × 5½ in., pp. 484. Illustrated. London, 1958: The Wire Industry Ltd. (Price 25*s*.)

The Comet 4 prototype . . . a steel furnace . . . a tinning line . . .

and now a man's heart reveals its performance on the strip chart of a Honeywell recorder. The recorder here tests the heart as a pump, diagnosing the 'hole-in-heart' condition in a few seconds. Honeywell ElectroniKs



Hole in the heart and other cardiac defects are now diagnosed pictorially at the National Heart Hospital, London. Honeywell's industrial Recorder traces continuously the concentration of injected dye as it passes through the bloodstream . . . indicates any disturbance in the pumping efficiency of the heart. The apparatus is produced by New Electronic Products Ltd.

combine research accuracy with resistance to wear and rough conditions. The thousands of varieties available ensure that any variable can be measured . . . by strip or circular chart recorders . . . by precision indicators . . . by multi-point recorders taking measurements from up to 20 points on the same chart. And in process control, ElectroniKs cover all requirements. Pneumatic and electric control models, with proportional, integral and derivative action, hold any process conditions at peak efficiency.

WRITE OR SEND THE COUPON TODAY for full information to:
Honeywell Controls Ltd. Ruislip Road East, Greenford, Middlesex. **Waxlow 2333**

My interests are as ticked:

Strip Chart Recorders	☐	Electric Controllers	☐
Circular Chart Recorders	☐	Pneumatic Controllers	☐
Multi-point Recorders	☐	ElectroniKs for research	☐

ElectroniKs for ..... *(Please state application)*

NAME .....

ADDRESS .....

OCCUPATION .....

JIBI

Branches in the principal cities of the U.K. and throughout the world.

Honeywell

First in Control

Surface Defects in Ingots and Their Products

DURING an investigation into the causes of ingot surface defects and their influence on the product, the Ingot Surface Defects Sub-committee of the British Iron and Steel Research Association became aware that there was a lack of uniformity in the names applied to the defects under review. To reduce the confusion of terms and promote a better understanding of the nature and causes of such defects, the Sub-committee selected those most commonly encountered and assigned to them the most apt term.

The first edition of this survey appeared in 1951 as No. 44 in The Iron and Steel Institute's Special Report Series, and was quickly sold out. In view of the many requests for copies of what is now a standard work of reference, it was decided to issue a second edition, with some important additional material.

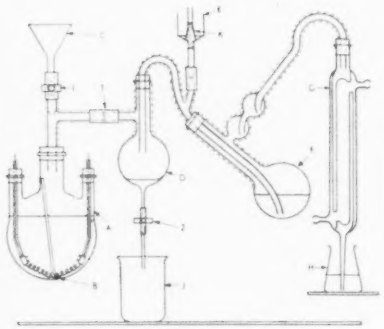
Through the courtesy of Richard Thomas and Baldwins Ltd., The Steel Company of Wales Ltd., and John Summers and Sons Ltd., the Sub-committee has been able to include an addendum devoted to surface defects in steel strip products.

The second edition is now available as **Special Report No. 63;** it consists of 62 quarto pages, illustrated with 134 excellent photographs of surface defects, and bound in cloth with stiff board covers.

The Report costs £1 5*s.* 0*d.* (15*s.* 0*d.* to Members), and may be obtained on application to

The Secretary
The Iron and Steel Institute 4 Grosvenor Gardens London SW1

The Determination of Nitrogen in Steel



Great interest has always been shown in the role of nitrogen in determining the properties of ferrous alloys. Reliable and accurate methods are therefore necessary for determining the content of this element in alloys.

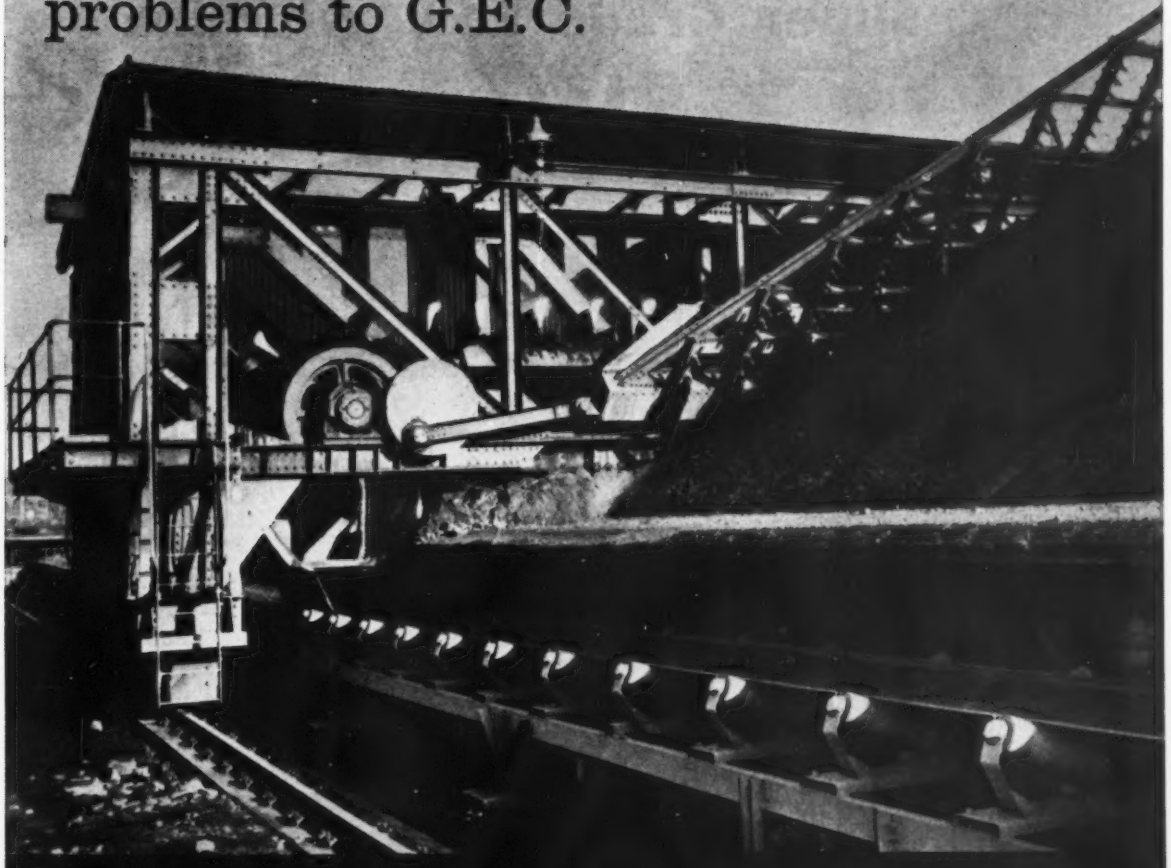
The establishment of the reproducibility and accuracy of analytical methods to serve as routine or reference procedures for the many alloys now produced is a major undertaking. It was for this reason that the Nitrogen Group of the Steelmaking Division of the British Iron and Steel Research Association was set up eight years ago. The Report of the Group has now been published as No. 62 in The Iron and Steel Institute's Special Report Series. The information it contains will be of inestimable value to all those interested in this subject.

The Report, which comprises 160 quarto pages and a number of illustrations, is bound in cloth with stiff covers, and costs £1 17*s.* 6*d.* (Members £1 5*s.* 0*d.*). It may be obtained from:—

I.S.I.
Special Report
No. 62

The Secretary,
The Iron and Steel Institute,
4 Grosvenor Gardens,
London, S.W.1.

Europe, too, takes its materials handling problems to G.E.C.



In modern blast furnace practice the blending of ores and coals is often essential. Robins-Messiter reclaimers of the latest G.E.C. design are meeting this very purpose all over the world.

The G.E.C. Erith Works specialise in the design and manufacture of complete ore and coal preparation plants. This includes conveyors, screens, crushers, stocking-out and reclaiming machines, wagon tipplers, sampling plants, bunkers and buildings. In fact, G.E.C. installations, handling and processing materials to and from sinter plants are dealing with capacities of 3,000,000 tons per year or more.

The G.E.C. have installed complete ore handling plant in the U.K., Belgium, Italy, Spain, Yugoslavia, Africa, Australia, etc. They are always pleased to advise companies contemplating such systems—especially at the pre-planning stage.

G.E.C. OF ENGLAND

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND
FRASER & CHALMERS ENGINEERING WORKS, ERITH, KENT

Designers and manufacturers of complete materials handling plant.

STEPHENS'

Super Grade Low Alumina
Silica Brick

•

FINE SILICA CEMENT FOR SETTING SILICA BRICK

•

STIGNIC CEMENT FOR BASIC STEEL LADLES

KILN CAPACITY OVER 1½ MILLION BRICKS

•

SPECIAL FIRE CEMENTS for all purposes

•

STEPHENS' SPECIAL ELECTRIC FURNACE ROOF BRICKS

REGENN BRICK without doubt the best Brick for Soaking Pits, Checkers, and Regenerator Chamber Walls

•

Stephens SILICA BRICK CO., LTD.
KIDWELLY

Telegrams:—STEPHENS, KIDWELLY,
Telephone:—KIDWELLY No. 1

Codes:—ABC 4th & 5th Editions
Liebers & Marconi

There's no excuse for

CORROSION

Many thousands of tons of steel are lost through corrosion every year and much of this can be saved. *There is a remedy.*
"Superlative" Metal Primer provides a positive protection against corrosion for all ferrous metals. It is quicker and easier to apply than conventional Lead Coatings and is infinitely cheaper. But, as *efficiency* is the factor that matters, and "Superlative" is so economical and so effective, it pays to specify

"Superlative"
METAL PRIMER

Kills **CORROSION AT THE SOURCE**

Our Techniservice will gladly answer all enquiries.

BRITISH PAINTS LIMITED

Portland Road, Newcastle upon Tyne, 2.
Crewe House, Curzon Street, London, W.1., 31, Wapping, Liverpool, 1.

BY APPOINTMENT TO HER MAJESTY QUEEN ELIZABETH II MANUFACTURERS OF PAINT BRITISH PAINTS LIMITED

BELFAST · BIRMINGHAM · BRISTOL · CARDIFF · GLASGOW · LEEDS · MANCHESTER · NORWICH · PLYMOUTH SHEFFIELD · SOUTHAMPTON · SWANSEA AND ALL PRINCIPAL TOWNS

INTRODUCING THE

SWINNEY MODUFLAME

Self Proportioning Oil Burner

Pat. applied for.

- *Single lever control*
- *Correct oil air ratio at all outputs*
- *Hot oil circulation to metering valve*
- *High combustion efficiency*

The Swinney Moduflame is an advanced type of Low Air Pressure Oil Burner. Control of output is effected by the operation of a single lever, automatically proportioning oil and air quantities in the correct ratio for all firing rates. High combustion quality is maintained over the whole operating range of the Burner resulting in savings in fuel cost and prolonging refractory life.

FOR FURTHER INFORMATION WRITE OR PHONE:—

SWINNEY BROTHERS LTD

MORPETH NORTHUMBERLAND Tel: MORPETH 92/3

LONDON: 34 CRUTCHED FRIARS E.C.3 Tel: ROYAL 2977

SWINNEY MORPETH ENGLAND

ACID RECOVERY OR DISPOSAL

THE COMPLETE SOLUTION

SULPHURIC ACID On high speed strip lines the new Kestner Recovery Plant offers maximum economy—freedom from fumes and low maintenance—low capital cost.

HYDROCHLORIC ACID On batch or continuous processes—a new process developed and used on the Continent—no by-product—good economy—no fumes.

SULPHURIC ACID On batch processes with limited output the well proven Kestner-Fakler process still offers the least expensive answer.

MIXED ACIDS Where acid recovery cannot be applied Kestner offer a complete range of neutralising plant employing various standard units.

May we give you further information

KESTNER EVAPORATOR & ENGINEERING CO. LTD.

5 GROSVENOR GARDENS, LONDON, S.W.1

Kestner

THE CHEMICAL ENGINEERS

FRESH AIR on the subject of CLEAN AIR

Fresh, clean air is always at a premium. VISCO 'Reciprojet' Air Filters automatically deal with dust contaminated air efficiently and economically. VISCO bring a fresh approach to the subject of ventilation and dust collection—ask us to tell you about 'Reciprojet' two-stage, automatic, self-cleaning air filtration. Cut costs by consulting THE VISCO ENGINEERING CO. LTD., STAFFORD ROAD, CROYDON. Telephone CROYDON 4181.

VISCO
Reciprojet
SELF-CLEANING
AIR FILTER

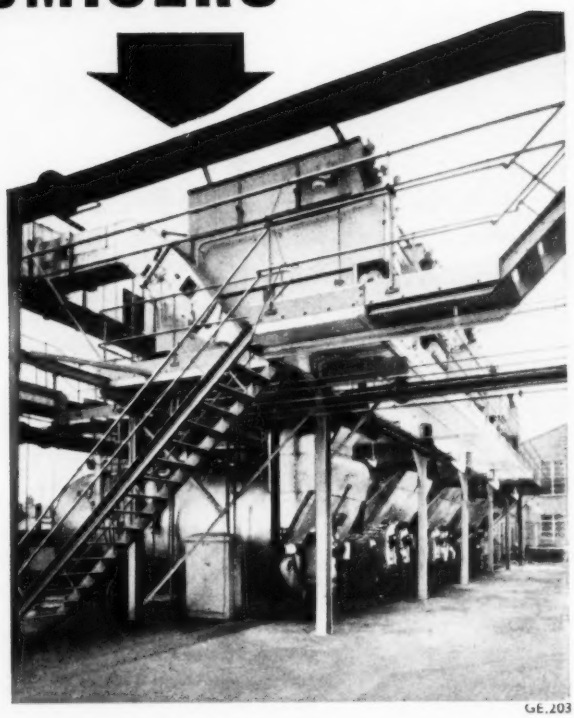
GREEN'S ECONOMISERS

with

ECONOMIC BOILERS

at I.C.I. SLOUGH

The Paints Division of Imperial Chemical Industries Limited of Slough operates an outdoor boiler plant, consisting of five John Thompson Economic boilers, four of 13,000 lb./hr. each and one of 7,000 lb./hr. oil-fired, designed working pressure 120 p.s.i. Mounted above each boiler is a Green's Premier Diamond Economiser.



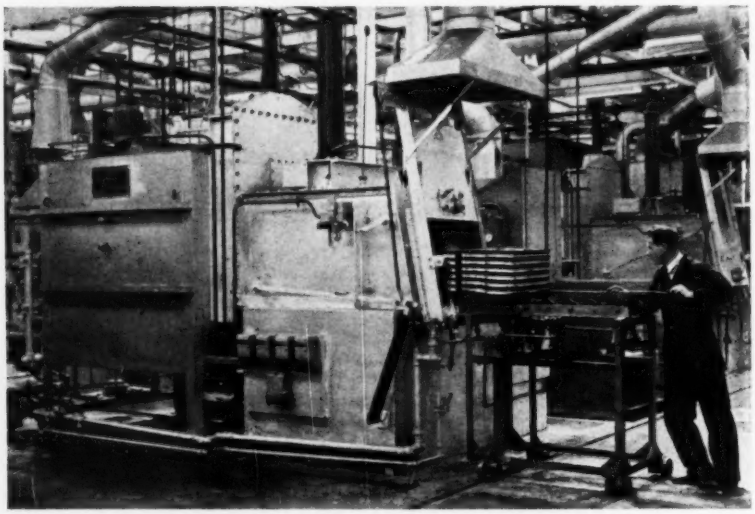
GE.203

E. GREEN & SON LTD.

WAKEFIELD

Makers of economisers for more than one hundred years

THE VERSATILE "ALLCASE" FURNACE



Processes—

With an operating temperature range of 1,400° to 1,750°F., the following controlled atmosphere processes can be carried out.

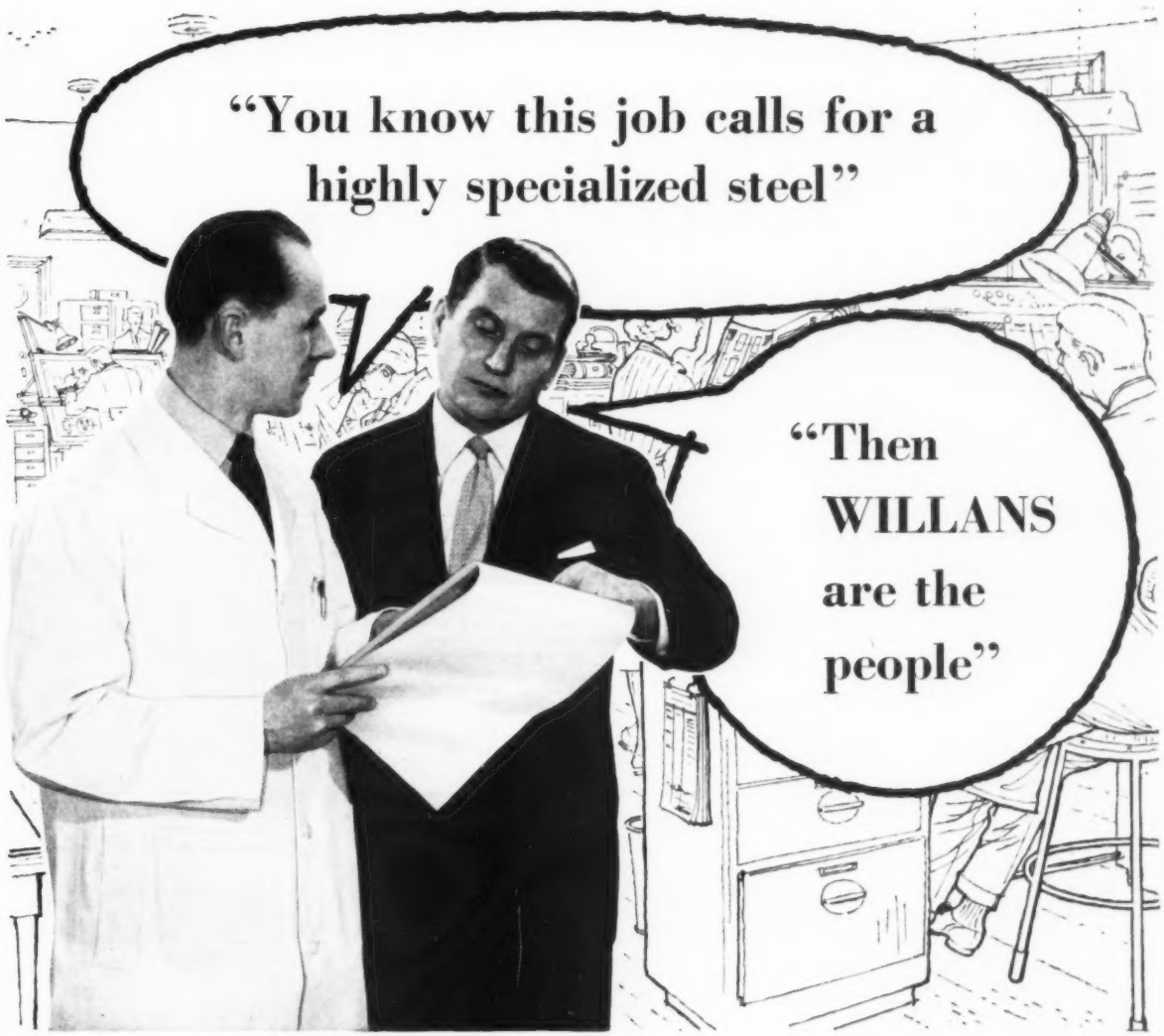
1. Gas Carburizing.
2. Hot Oil or Marquenching.
3. Clean Hardening.
4. Dry Cyaniding or Carbonitriding.
5. Carbon Restoration.
6. Homogeneous Carburizing.
7. Clean Annealing.

The two "Allcase" furnaces

illustrated are at the works of a leading motor manufacturer, and are used for carburising and carbonitriding steering and other parts, requiring various case compositions and depths. The hearth area of each furnace is 3′ 0″ × 2′ 0″ with 1′ 6″ permissible depth of charge, and is designed to accommodate gross charge weights varying from 900 lbs. at 750°C. to 500 lbs. at 950°C.

British Furnaces Limited - Chesterfield

ASSOCIATED WITH SURFACE COMBUSTION CORPORATION, TOLEDO, U.S.A.



A job that calls for a special steel? Then call in Willans, the specialists. With their air-melting electric furnaces and modern high-vacuum melting equipment, they can produce up to 250 tons of special quality steels per month, including stainless and tool steels, and steels for nuclear energy equipment. All are made under strict standards of metallurgical control. For quick deliveries of all 'specials' in steels, call in Willans *at once*!

G. L. WILLAN LTD

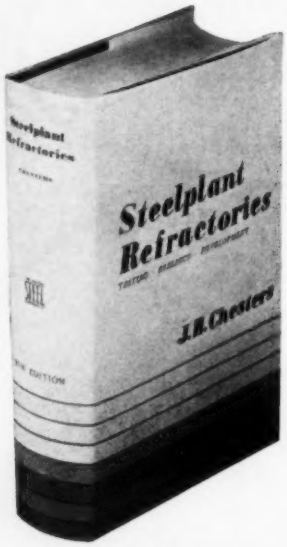
(Approved A.I.D., D.I. Arm. A.R.B.)
Steel and Alloy Manufacturers

SUSSEX STREET · SHEFFIELD 4 · TELEPHONE: 24211

OAS157

"....destined to be, and deserves to be, a best seller"

Refractories Journal



728 Pages
274 Illustrations

The New Entirely Revised Edition of

Steelplant Refractories

by

J. H. Chesters

Transactions of The British Ceramic Society:
... No greater tribute could be paid to Dr. Chesters than to say that he has not only arranged his material in an orderly and logical sequence but has presented it with enthusiasm and imagination ... refractory problems become an exciting challenge which cannot fail to appeal to the reader ...

Engineering
... The information available on every one of its 728 pages offers experience, which no engineer or chemist could hope to gain in a lifetime of practical observation ...

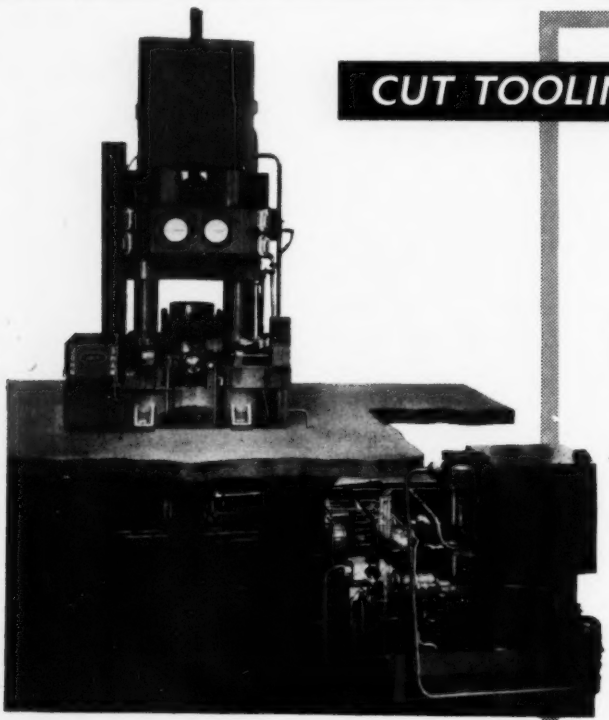
Blast Furnace and Steel Plant
This second edition should find its way into every steelplant and into the hands of all who produce, test, study or use steelplant refractories. The author is uniquely qualified to write on this subject for an international readership .... Perhaps the best way of giving an over all idea of its nature is to predict that most readers will find it so full of ideas that, like this reviewer, they will make a series of memos beginning: 'Let us try this out ...'

PRICE £4 Sterling $12 U.S.A. or Canada.

Post Free

The Publications Department · The United Steel Companies Limited · 17, Westbourne Road, Sheffield, 10

US132



CUT TOOLING COSTS TO A TENTH

with the sensational new

SHAWDRAW

DEEP DRAWING PRESS

The SHAWDRAW gives accuracy with economy by combining the best features of the steel die and rubber pad processes.

You SAVE—in tooling, a pressurised rubber diaphragm, with pre-set variable pressure/stroke cycle, replacing the female die.

—in labour costs, so foolproof is the design that unskilled labour can safely be used.

You GAIN—amazing accuracy, for springback is virtually eliminated and "thinning" is negligible.

—an infinitely improved finish.

—reductions up to 75% under ideal conditions and 60% with D.D.Q. materials normally.

You MUST know more about the SHAWDRAW—write today for full details of this remarkable press.

SHAWDRAW presses are available in 18", 23" and 26" sizes.

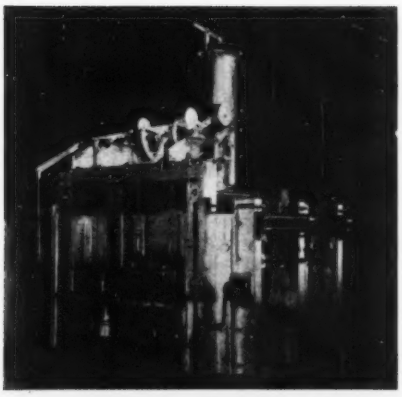
JOHN SHAW & SONS (SALFORD) LIMITED
SALFORD LANCASHIRE

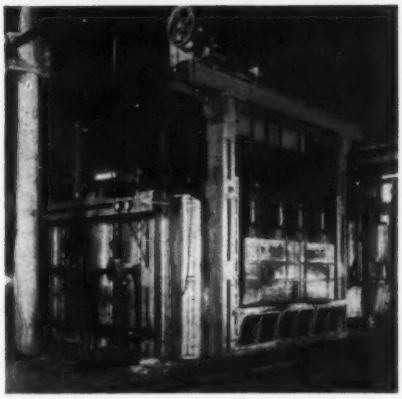
Modern Forge Furnaces

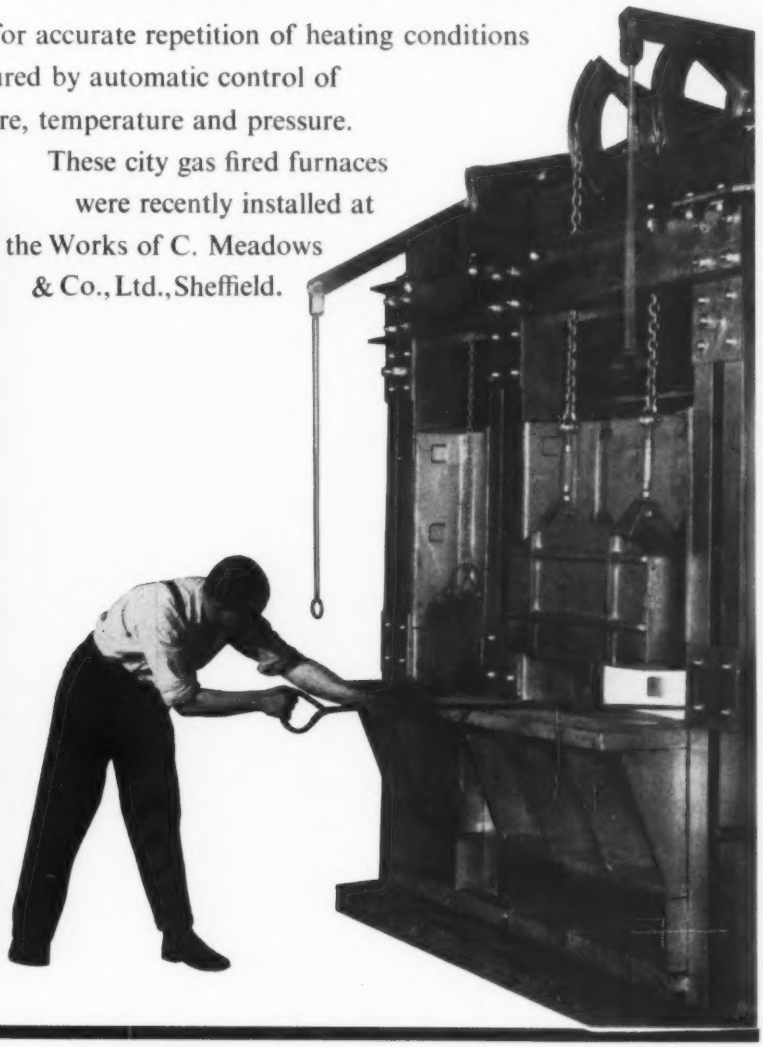
FIRED BY FUEL OIL, PRODUCER GAS OR CITY GAS

The increased demands for accurate repetition of heating conditions is ensured by automatic control of furnace atmosphere, temperature and pressure.

These city gas fired furnaces were recently installed at the Works of C. Meadows & Co., Ltd., Sheffield.





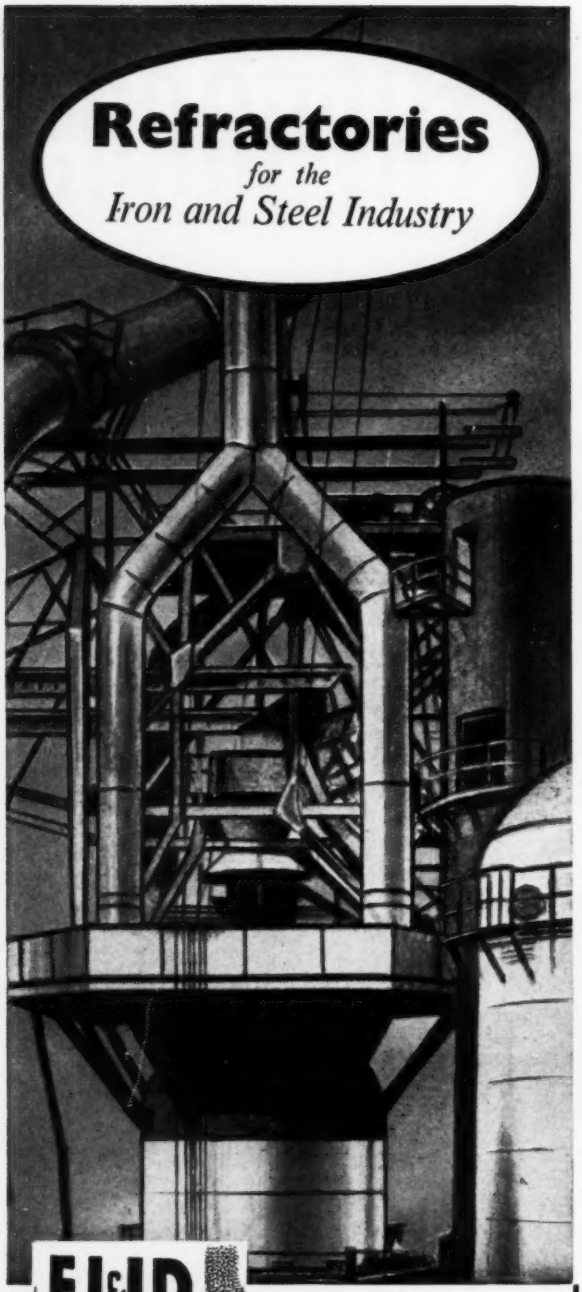


WINCOTT FURNACES

G.P. WINCOTT LIMITED SHEFFIELD, ENGLAND

Telegrams: WINCOTT, SHEFFIELD Telephone: 20211/2

SBW20



Refractories
for the
Iron and Steel Industry

EJ&JP

Pearson consistent quality refractories are available in standard brick sizes in a wide range of materials. Special shapes of all types also made to order.

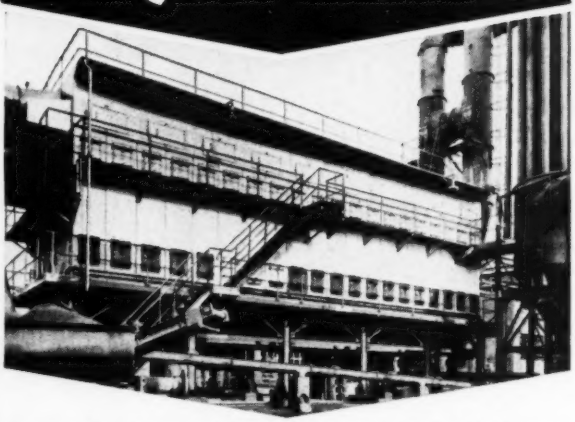
Send for full technical information and prices.

FIRECLAY, HIGH ALUMINA, SILLIMANITE AND SILICON CARBIDE BRICKS AND SPECIAL SHAPES. INSULATING BRICKS AND CONCRETE. PLASTIC JOINTING AND PROTECTIVE CEMENTS, REFRACTORY CONCRETE AND RAMMING COMPOUNDS.

E. J. & J. PEARSON LIMITED
FIREBRICK WORKS, STOURBRIDGE
Telephone: Brierley Hill 77201

SOLVE YOUR DUST & SMOKE PROBLEMS WITH

INTENSIV FILTER EQUIPMENT



especially designed for the Iron & Steel Industry

"Intensiv" Dust Filters have been used in the Iron and Steel Industries of Europe, for over 35 years. During this long period they have been tested under every conceivable condition—tested and found good.

The range of equipments available in Great Britain are as follows:

INTENSIV — Bag Filter
INTENSIV — Cyclons
INTENSIV — Chamber Dedusting
INTENSIV — Coolers
INTENSIV — Fans
INTENSIV — Filtering Bags

INTENSIV—FILTER GMBH LANGENBERG/Rhl'd

Officially appointed representative in Great Britain

L. E. CROOKS
119 MOORGATE, LONDON, E.C.2.

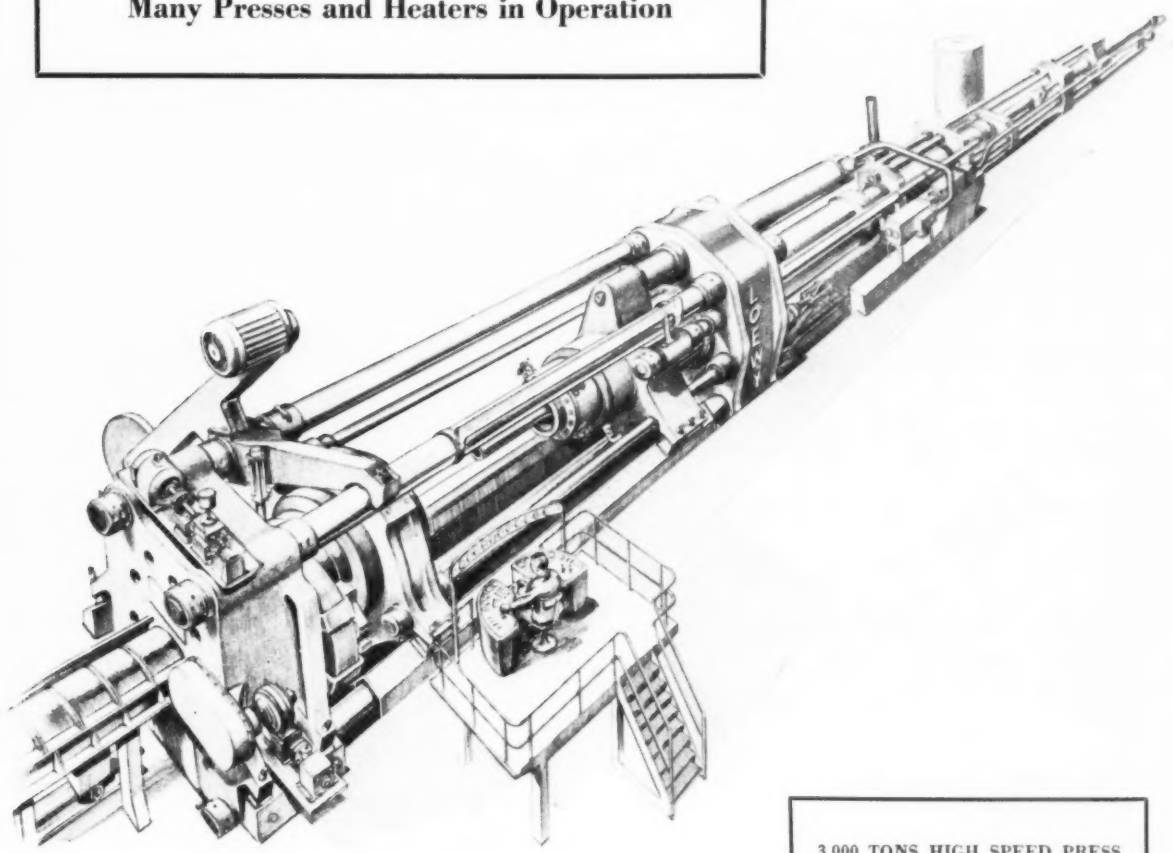
STEEL EXTRUSION

Steel Extrusion Plant now on order:-

4 **Extrusion Presses with** **22**

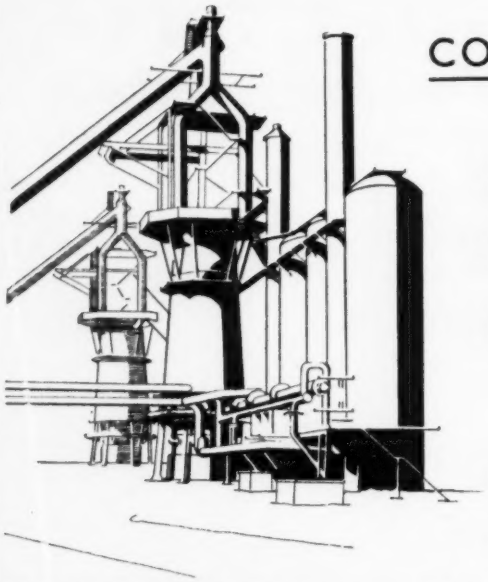
'LOEWY'-'MAGNETHERMIC' Billet Heaters.

Many Presses and Heaters in Operation



3,000 TONS HIGH SPEED PRESS
FOR THE EXTRUSION OF
TUBES AND SECTIONS IN
CARBON AND ALLOY STEELS

THE **LOEWY** ENGINEERING COMPANY LTD.
BOURNEMOUTH ENGLAND



COMPLETED LININGS TO

51 BLAST FURNACES

99 HOT BLAST STOVES

52 STEEL MELTING FURNACES

BRICKS LAID YEARLY — 12 MILLION

STAFF — 80 FURNACE BRICKLAYERS

TATTERSALL

REFRACTORY CONTRACTORS

137, SOUTHFIELD ROAD

MIDDLESBROUGH.

THE LANARKSHIRE STEEL Co. Ltd.

Structural Steelwork
Colliery Arches
Forging Blooms
Sections
Joists
Slabs

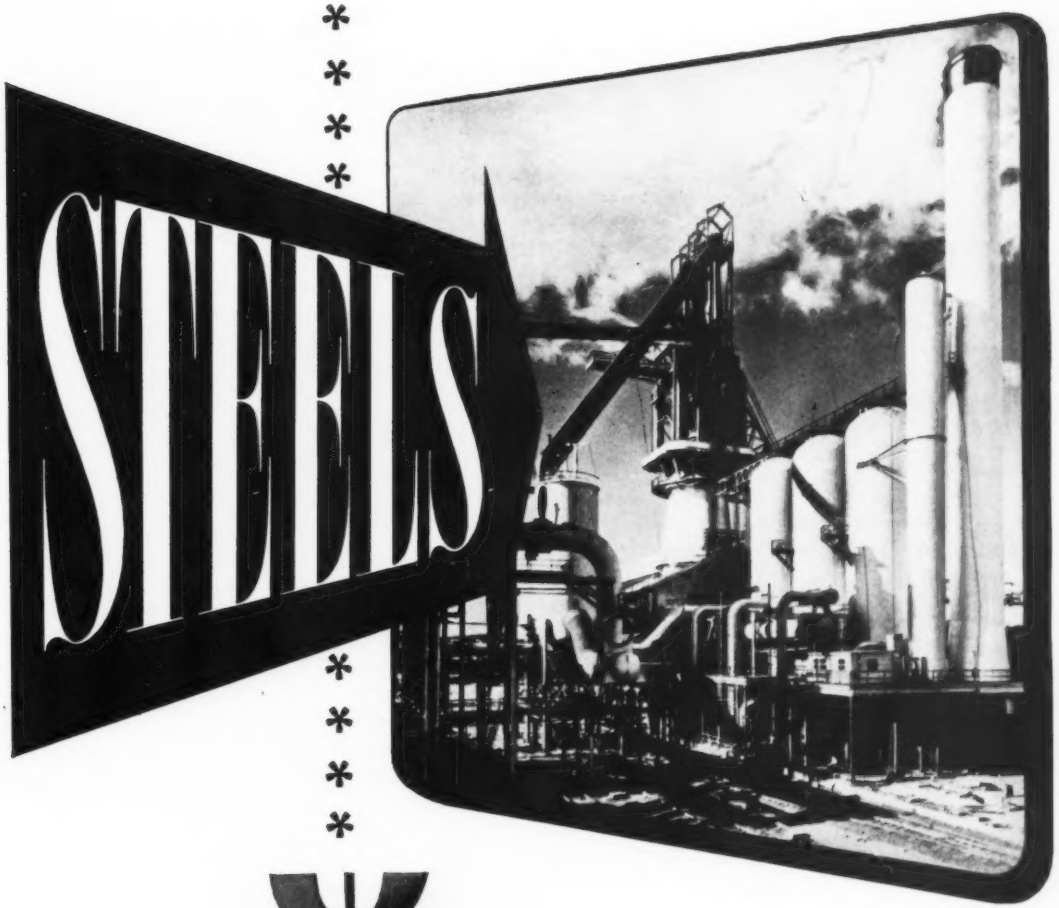
★ ★

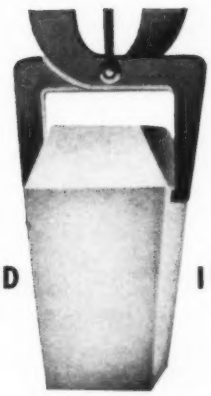
Works and
Head Office:—
FLEMINGTON
MOTHERWELL

Phone: - Motherwell 347

COLVILLES LIMITED

INTERPRETING THE PRESENT AND PLANNING THE FUTURE!





FITNESS FOR PURPOSE STEELS

COLVILLES LIMITED 195 WEST GEORGE STREET · GLASGOW C 2

Index to Advertisers

Adamson-Alliance Co. Ltd. 18
Adamson Joseph and Co., Ltd. 42
A. E. I. Heavy Plant Division 30
Allen West & Co., Ltd. 48
Armstrong Whitworth (Metal Industries) Ltd. 54
Arrol, Sir Wm., & Co., Ltd. ... ... —
Ashmore, Benson, Pease, & Co. Inside Back Cover

Bairds & Scottish Steel, Ltd. ... ... —
Beardmore, William, & Co., Ltd. ... ... —
Bigwood, Joshua, & Sons, Ltd. ... ... —
Birfield Industries Ltd. 3
Birlec-Efco (Melting) Ltd. ... ... —
Boby, William & Co., Ltd. ... ... —
Bonnybridge Silica & Fireclay Co., Ltd. —
Bradley & Foster Ltd. ... ... —
Brightside Foundry & Engineering Co., Ltd., The 24
British Acheson Graphite Ltd. 46
British Electrical Development Association 41
British Furnaces, Ltd. 74
British Oxygen Gases, Ltd. ... ... —
British Paints, Ltd. 71
British Rollmakers Corporation, Ltd. ... —
British Thomson-Houston Co., Ltd., The —
British Timken, Ltd.... 51
Brown Bayley Steels, Ltd. 40
Burn Fireclay Co. Ltd., The ... ... —
Bushing Co., Ltd., The 21

Carblox Ltd. ... ... —
Coalmoor Refractories Ltd. ... ... —
Colvilles, Ltd. 81
Consett Iron Co., Ltd. 37
Constables (Matlock Quarries) Ltd. ... —
Contactor Switchgear, Ltd. 28
Coppee Co. (Gt. Britain) Ltd., The ... 16
Cox & Danks, Ltd. ... ... —
Craven Bros. (Crane Division), Ltd. ... 14
Crofts (Engineers) Ltd. 20
Crooks, L. E. 78

Davy & United Engineering Co., Ltd. 66
Dewhurst & Partner, Ltd. 43
D.M.M. Machinery, Ltd. 44
Dyson, J. & J. Ltd. Inside Front Cover

Edwards High Vacuum Ltd. ... ... —
Electroflo Meters Co. Ltd. ... ... —
English Electric Co., Ltd., The ... ... —
English Steel Corporation, Ltd. 39
Evershed & Vignoles Ltd. ... ... —

Fischer Governor Co. Ltd. 59
Foster, Henry, & Co., Ltd. ... ... —
Foster Instrument Co. Ltd.... ... ... —
Fraser & Chalmers ... ... —
Fuller's Earth Union Ltd., The ... ... —

Gas Council, The 8, 9
General Electric Co., Ltd., The 69
General Refractories, Ltd. 50
Gibbons Brothers, Ltd. 47
Glenboig Union Fire Clay Co., Ltd. ... —
Green, E., & Son, Ltd. 74
Guest Keen Iron & Steel Co., Ltd. ... 60
Guest, Keen & Nettlefolds, Ltd. ... ... —
G.W.B. Furnaces, Ltd. ... ... —

Hadfields, Ltd. ... ... —
Harland Engineering Co., Ltd. ... ... —
Head, Wrightson, Iron & Steel Works Engineering, Ltd. ... ... —
Head, Wrightson Machine Co., Ltd. 52, 53
Heywood, S. H. & Co., Ltd. ... ... —
High Speed Steel Alloys Ltd. ... ... —
Holmes, W. C. & Co., Ltd. 62
Holset Engineering Co., Ltd. ... ... —
Honeywell-Controls, Ltd. 67
Howden, James & Co., Ltd. ... ... —
Hudswell Clarke & Co., Ltd. 32
Hunslet Engine Co. Ltd. ... ... —
Huntington, Heberlein & Co. Ltd. ... 27

Igranic Electric Co., Ltd. ... ... —
Ilford, Limited 22
Imperial Chemical Industries Ltd. 4
International Construction Co., Ltd., The 57

Johnson's Rolls Ltd. ... ... —
Johnson Matthey & Co., Ltd. 61

Kelvin Hughes Ltd. 15
Kestner Evaporator & Engineering Co., Ltd. 72
King, Geo. W., Ltd. ... ... —
Kingscliffe Insulating Products, Ltd. ... 25

Lamberton & Co., Ltd. Outside Back Cover
Lanarkshire Steel Co., Ltd., The 80
Lancashire Steel Manufacturing Co. Ltd. ... 26
Lodge-Cottrell, Ltd. 13
Loewy Engineering Co. Ltd., The 79
Lysaght's John, Scunthorpe Works Ltd. ... 17

Marshall, Thomas, & Co. (Loxley), Ltd. ... —
Metallurgical Engineers Ltd. ... ... —
Metropolitan Vickers Electrical Co., Ltd.... —
Michigan (Gt. Britain) Ltd.... ... ... —
Mobil Oil Co. Ltd. ... ... —
Mitchell Engineering Ltd. 5
Mond Nickel Co., Ltd. 12
Moorwood, John M., Ltd. ... ... —
Morgan Crucible Co., Ltd., The ... ... —
Morgan Refractories Ltd. 36
Morgardshammars Mekaniska Verkstads AB 56
Moxey, Ltd. ... ... —

National Industrial Fuel Efficiency Service ... —
Newalls Insulation Co. Ltd. ... ... —
Newell, Ernest, & Co., Ltd. ... ... —
Newton, Chambers & Co., Ltd. ... ... —

Oughtibridge Silica Firebrick Co. 55

Park Gate Iron & Steel Co., Ltd.... ... ... —
Parsons, C. A. & Co., Ltd. ... ... —
Pearson, E. J. & J., Ltd. 78
Phillips Electrical Ltd. ... ... —
Phosphor Bronze Co., Ltd., The 3
Pickford Holland & Co., Ltd. 2
Power-Gas Corporation Ltd., The Inside Back Cover
Priest Furnaces, Ltd. 10

R-N Process Agency 33
Railko Ltd. ... ... —
Rawlplug Co. Ltd., The 45
Research & Control Instruments Ltd. ... —
Richardsons Westgarth & Co. Ltd. ... —
Roberts, J. W. Ltd. ... ... —
Robertson, W. H. A., & Co., Ltd. 49
Ross Engineers Ltd.... 19

Salem Engineering Co., Ltd. ... ... —
Schloemann ... ... —
Shaw, John, & Sons (Salford) Ltd. 76
Shell-Mex & B.P., Ltd. 34, 35
Siemens Edison Swan, Ltd. ... ... —
Simon-Carves, Ltd. ... ... —
Skefko Ball Bearings Co. Ltd., The ... —
Smith, John (Keighley), Ltd. 76
Smith, Thomas & Sons (Rodley) Ltd. ... —
Smith & McLean, Ltd. 58
Spencer-Bonecourt-Clarkson Ltd. ... —
Strachan & Henshaw Ltd. ... ... —
Stanton Ironworks Co., Ltd., The ... ... —
Steel Co. of Wales, The 29
Stein & Atkinson, Ltd. ... ... —
Stein, John G., & Co., Ltd. ... ... —
Stephens Silica Brick Co., Ltd. 70
Stewarts & Lloyds, Ltd. ... ... —
Stillite Products Ltd. 11
Summerson, Thos., & Sons, Ltd. ... ... —
Sunvic Controls Ltd. ... ... —
Swinney Bros. Ltd. 70

Tattersall & Son Ltd. 80
Thermal Syndicate Ltd. ... ... —
Thomas (Richard) & Baldwins, Ltd. ... —
Thornton, B., Ltd. 31

Union Carbide Ltd. 23
United Coke & Chemicals Co. Ltd. ... 6
United Steel Companies Ltd. 76

Vaughan, Edgar, & Co., Ltd. ... ... —
Visco Engineering Co., Ltd. 73

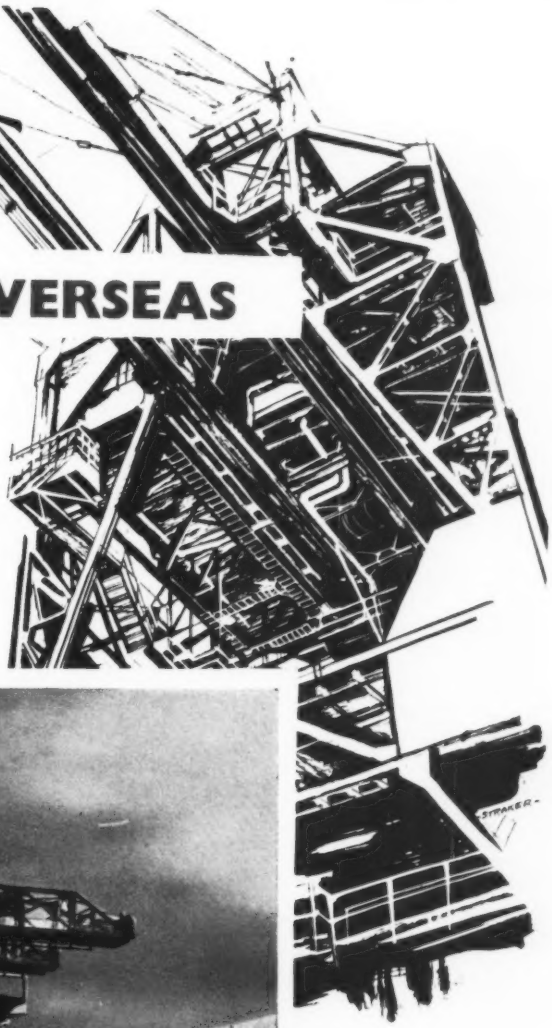
Ward, Thos., W., Ltd. 7
Warner & Co., Ltd. ... ... —
Wellman Bibby Co. Ltd. ... ... —
Wellman Smith Owen Engineering Corporation Ltd., The 1
West Hunwick Silica & Firebrick Co., Ltd. —
Whitehead Iron & Steel Co., Ltd. 38
Wild Barfield Electric Furnaces Ltd. ... —
Willan, G. L. Ltd. 75
Wincott, G. P., Ltd. 77
Woodall-Duckham Construction Co., Ltd. 64

Published at the offices of The Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1, and Printed in Great Britain by HARRISON & SONS, LTD., by Appointment to Her Majesty The Queen, Printers, London, Hayes (Middx.) and High Wycombe.

LAMBERTON

ORE HANDLING OVERSEAS

Overseas contracts include:
Two ore unloaders, each with 15 ton capacity grabs, with a combined handling capacity of 3,000 tons per hour.
One ore bridge, 560 ft. long, with 18 ton capacity grabs capable of handling 1,500 tons per hour.



Two ore unloaders, at a large steelworks in Argentina, equipped with 12½ ton capacity grabs jointly handling 2,200 tons of ore per hour.

ASHMORE, BENSON, PEASE & COMPANY

MEMBER OF **THE POWER-GAS GROUP**

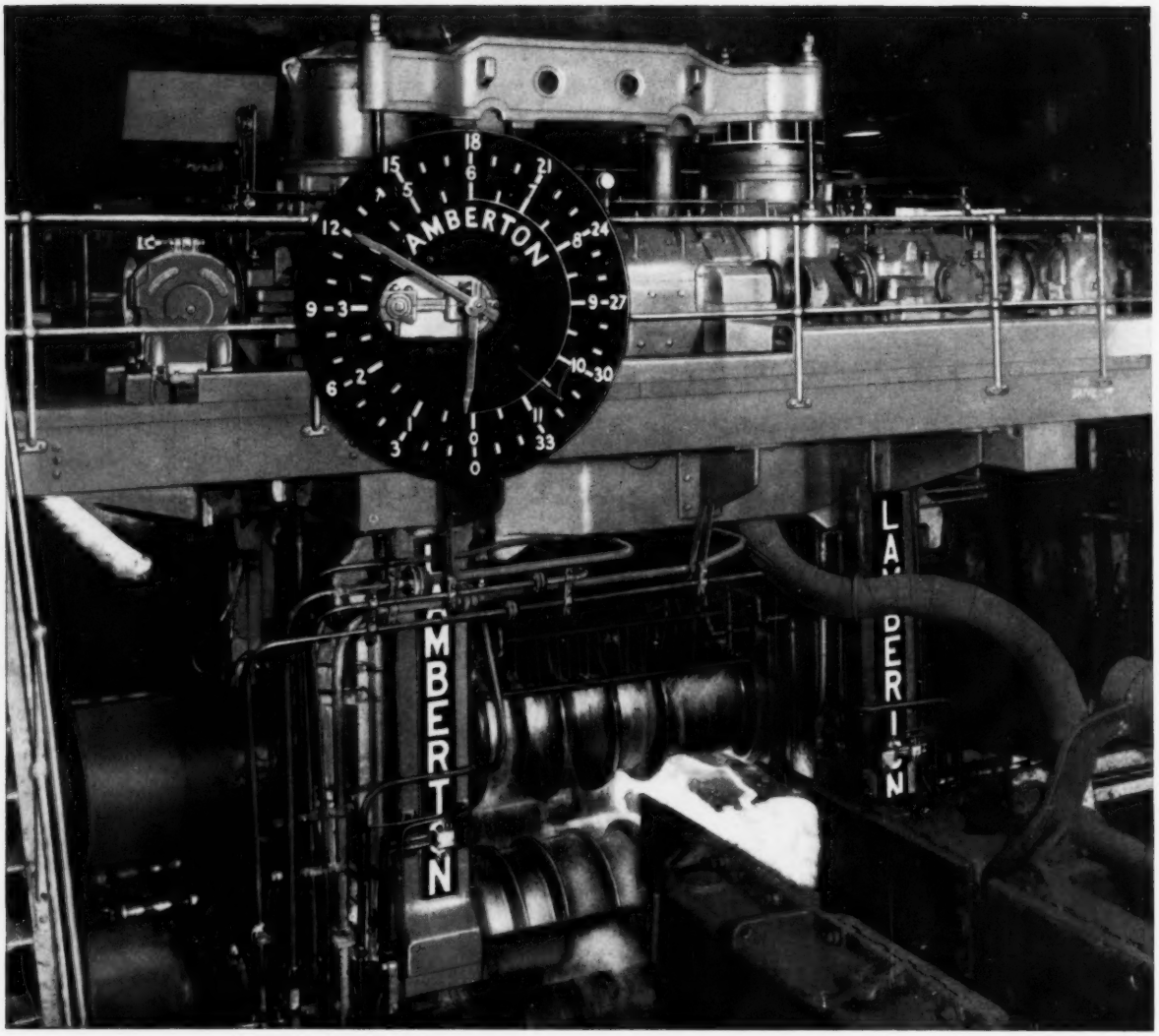
(In association with McKiernan-Terry Corpn. (Mead-Morrison Divn.) U.S.A.)

STOCKTON-ON-TEES AND LONDON

384 AUSTRALIA · CANADA · INDIA · FRANCE · SOUTH AFRICA

LAMBERTON

steel works plant



42" BLOOMING MILL

in operation at the Lancashire Steel Corporation, Irlam Works.

MAKERS OF STEELWORK PLANT
FORGING MACHINERY SHEARS, ETC.

LAMBERTON
COATBRIDGE
SCOTLAND